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Online Support of Interdisciplinary Student Projects

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Technology

Espoo, January 17, 2017
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Abstract of master's thesis

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Abstract

The aim of this work is to investigate, how project courses can be supported with online tools. Especially learning in projects and supporting the progression of projects is inspected. The ultimate goal would be that the students would form a team and get started fluently as well as work efficiently in projects while also learning and getting feedback. Practical online methods are created especially for the needs of mechatronics and cell biology student projects at Aalto University.

The literature review examines interdisciplinary projects, learning, teaching and assessment in projects, phases of a project and project management and software used in project courses. Challenges of projects are presented with the help of questionnaire results at the beginning of the research part. Different types of preliminary methods have been developed to tackle these challenges. These include a formation of a team exercise, instructions for online project management, visualizing a course process with a diagram as well as tools for self- and peer-assessment. A case course was available to test some of the methods. The experiences of the students were inspected with a questionnaire. Based on the research, a plan was created for example projects, where students in a cell biology course and students in a mechatronics course will cooperate. The plan includes, what the students do together and what separately and what teaching methods are used.

This research provides the reader a good understanding about the utilization of online methods in project courses. It is brought out how the visualization of different aspects can support the progression of a project and what kind of documentation and instruction should be utilized. Based on the research, several practical recommendations can be given. For example, asking students to write down and share their working time was found to even out the workload of a team and the documentation of the students from previous years was seen as a useful baseline for the new students.

Keywords engineering education, project course, blended learning

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Tiivistelmä

Tämän työn tarkoituksena on tutkia, miten projektikursseja voidaan tukea verkkopohjaisilla menetelmillä. Erityisesti tarkastellaan oppimista projekteissa ja projektien etenemisen tukemista. Tavoitteena olisi, että opiskelijat ryhmäytyvät ja pääsevät liikkeelle sujuvasti sekä työskentelevät tehokkaasti projektissa samalla oppien ja saaden palautetta. Työssä on erityisesti tarkoitus luoda käytännöllisiä verkkopohjaisia menetelmiä Aalto-yliopiston mekatroniikan ja solubiologian opiskelijaprojekteja varten.

Kirjallisuusselvityksessä tehdään katsaus monitieteisiin projekteihin, projekteissa oppimiseen, projektikurssien opettamiseen ja arviointiin, projektien vaiheisiin ja projektinhallintaan sekä projektikursseilla käytettyihin verkkopohjaisiin työkaluihin. Tutkimusosiossa on esitetty projektien haasteita kyselytulosten avulla. Verkkopohjaisia menetelmiä kehitettiin vastaamaan näihin haasteisiin. Näihin menetelmiin lukeutui ryhmäytymisharjoitus, ohjeistus verkkopohjaiseen projektinhallintaan, kurssin etenemisen visualisointi, sekä työkalu itse- ja vertaisarviointia varten. Tutkimusta varten oli käytössä case-kurssi, jolla osaa menetelmistä testattiin. Opiskelijoiden kokemuksia kerättiin kyselytutkimuksella. Tutkimuksen perusteella luotiin suunnitelma esimerkkiprojekteille, joissa solubiologian ja mekatroniikan kurssien opiskelijat tekevät yhteistyötä. Suunnitelma käsittää sen, mitä asioita opiskelijat tekevät yhdessä ja mitä erikseen, ja millaisia opetusmenetelmiä käytetään.

Tämä työ tarjoaa lukijalle hyvän perusymmärryksen verkkopohjaisten menetelmien hyödyntämisestä projektikursseilla. Työssä tuodaan esille, millä tavoin projektin tekijöiden visualisointi voi tukea projektin etenemistä ja millaisia dokumentaatioita ja ohjeistuksia projekteissa tulisi hyödyntää. Tutkimustulosten perusteella voidaan antaa myös useita käytännön suosituksia. Esimerkiksi opiskelijoiden työskentelyajan kirjaamisen havaittiin tasaavan ryhmän työkuormaa ja edellisten vuosien opiskelijoiden tuottama dokumentaatio nähtiin hyödyllisenä vertailukohtana uusille opiskelijoille.

Avainsanat insinööriopetus, projektikurssi, monimuoto-opetus

Preface

This thesis is written for the needs of project courses in Aalto University in the new digital era. The research is funded and made possible by Biology meets Mechatronics pilot in Aalto Online Learning project. I want to thank Aalto University for investing in the digitalization of learning, and encourage the University to engage in systematic development in the area.

I want to thank all the people involved in the Biology meets Mechatronics pilot. It has been inspiring to work with people from different backgrounds. I am grateful to Tua Björklund and Tapio Auvinen for interviews that helped me to see this thesis in its context. Thanks to all people in the corridor of Machine design for being nice. I owe much to Professor Petri Kuosmanen also, who has supported me throughout my studies and volunteered for being the supervisor of this thesis.

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Espoo, January 17, 2017

Tommi Lintilä

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Acronyms

A!OLE	Aalto online learning
C&T	Cell and Tissue Engineering
PBL	Problem-based learning
SRL	Self-regulated learning
MLSQ	Motivated Strategies for Learning Questionnaire
MP	Mechatronics Project
LASSI	Learning and Study Strategies
SRLIS	Self-Regulated Learning Interview Scale
OSLQ	Online Self-Regulated Learning Questionnaire
SRL-SRS	Self-Regulation of Learning Self-Report Scale
PMS	Project Management Software
ZPD	Zone of proximal development
PEF	Perceived effectiveness factor

1 Introduction

1.1 Background

E-learning methods are being applied more and more in university teaching. They can offer a solution to handle an increasing amount of students with less teaching resources by streamlining and automating simple teaching tasks, at the same time providing the teacher with a possibility to concentrate on essential teaching efforts like interaction with the students. Projects are unique ventures that have a defined scope for a goal, a timeframe, a budget and team members. This thesis initiates from Biology meets Mechatronics pilot funded by Aalto University's Aalto Online Learning (A!OLE) project. Within A!OLE, several pilots are created to develop online learning experiences (Kauppinen 2016). The aim of the pilot is to develop online teaching methods in order to support collaborative project work with students from the fields of cell biology and mechatronics.

This research provides a plan for the collaborative projects of students from courses Cell- and Tissue Engineering and Mechatronics Project. Cell- and Tissue Engineering is a 5 ECTS course for master students with lecturing and project content. Mechatronics Project is a master level 10 ECTS course, in which students design and build a mechatronic machine or system. The project topics are usually based on research projects and the students have also involved in research in addition to developing a device.

1.2 The research problem

Many students see project courses as their favorite ones, as they are given the possibility to build something on their own. Still, there are multiple challenges and improvement possibilities in project courses with open-ended topics. Commonly, a teacher cannot be watching over all the time, what the students are doing. Somehow the students organize themselves, learn by doing and are able to finish a project. Could the results of learning in projects be improved by including more guidance and instructions?

University project courses should enable the adopting of working life skills. Today, these include being able to use digital tools to improve working efficiency and being able to work in an interdisciplinary team. At the same time, teachers are given more and more responsibilities. Digital and online tools and methods should be applied for the more efficient use of teachers' time.

1.3 Goals for the study

This thesis aims to show the main challenges of interdisciplinary projects. The goal is to study and develop different online methods to support the progression and enhanced learning in interdisciplinary project work. In addition, documentation and assessment of projects will be investigated. In the end, an implementation plan is developed for the first Biology meets Mechatronics projects to be run during spring term 2017.

1.4 Scope of the Research

Perspective is in the view of developing online tools for interdisciplinary student projects. The aim in these projects is to create a physical product. As student projects are investigated, there are also clear objectives for learning in the project. Still, the research done and models proposed should be applicable in any interdisciplinary project work. While investigating online tools and methods, the projects will not be run online. Digital tools are looked for improvement of running normal physical projects. Also, the tested methods are implemented in available platforms. The possibility to develop an online platform is left for further studies. The research area is so vast that in-depth reviews are not possible. Rather, the focus will be on investigating different approaches and possibilities to help the decision on where to focus on further research in the field of online project support.

1.5 Research methods

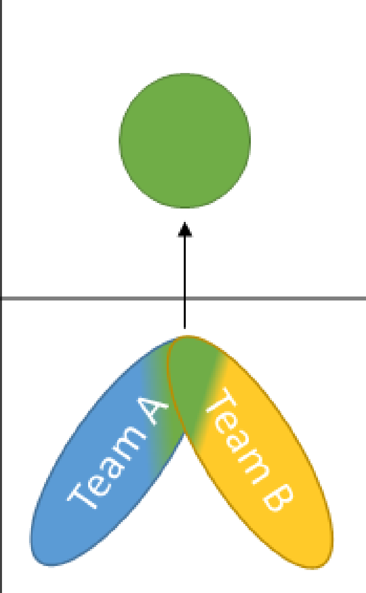
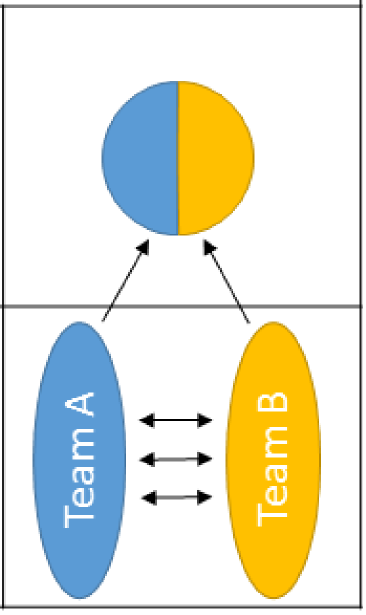
In the literature review, different aspects of learning in project courses, their challenges and possible online tools are investigated. Preliminary online methods were implemented in Mechanical and Structural Engineering Laboratory course. Their usability were tested in a student questionnaire and by analyzing the student use of tools. The literature review and test results are used to create a suggestion for the forthcoming Biology meets Mechatronics pilot projects.

2 Literature review

2.1 Interdisciplinary project work

It can be discussed whether the topic of this thesis should contain a term multidisciplinary instead of a term interdisciplinary. The differences in these types of working are shown in Table 1. Interdisciplinary is defined as integrated cooperation between disciplines to create something that is not possible to define with only the knowledge of one discipline (Choi & Pak 2006). Multidisciplinary work involves multiple disciplines in the same project, but the disciplines are acting more or less separately (Choi & Pak 2006). The aim in designing Biology meets Mechatronics pilot projects is to create truly interdisciplinary cooperation between the students, as explained in Chapter 4.

Table 1. The difference between interdisciplinary and multidisciplinary.

Interdisciplinary		Multidisciplinary	
The product represents a new cross-discipline		The product represents a combination of disciplines	
Teams from different disciplines are integrated		Teams from different disciplines work separately	

Teaching a project work with multiple disciplines is reasonable, as broad collaboration is needed to face the increasingly complex technological challenges (Richter & Paretti 2009). Diversity in a project team may improve problem solving and creativity (Choi & Pak 2007). Students should be prepared for what awaits them in the working life.

A comprehensive planning for the interdisciplinary learning units is needed (Richter & Paretti 2009). Having students from different disciplines in the same project is an arrangement that does not necessarily improve the working skills of the students by itself. Learning objectives for interdisciplinary cooperation with corresponding teaching interventions should be created (Richter & Paretti 2009). Richter and Paretti (2009) propose the interdisciplinary collaboration and learning outcomes for the students as understanding the approaches, expertise and needs of multiple fields and being able to identify how their disciplinary expertise can contribute to a solution of an interdisciplinary problem. Interdisciplinary learning outcomes do not have to be integrated into the learning outcomes of the concerned courses, but they should be thought of when planning the implementation of the courses.

Challenges specific to interdisciplinary projects relate to the difference between the disciplines. Team members might not understand the relationship between their own discipline and an interdisciplinary subject (Richter, Paretti 2009). They might not be able to recognize or value the contributions of other fields to a given technical problem (Richter, Paretti 2009). Team members have different expectations for their own and the others' roles, which leads to misunderstandings (O'Brien et al. 2003). They do not know, what the information needs of the other team members are and how to work within and across disciplines (O'Brien et al. 2003). Experts from different disciplines use different language (Choi & Pak 2007). Unequal power among disciplines may lead to that project are more oriented to one discipline (Choi & Pak 2007). In student projects, it is a challenge to find and clarify roles for each team member. This is the case especially if there are less active members, many representatives from the same disciple (Rekonen & Björklund 2016) or students with no clear skill set. Project management of an interdisciplinary project should aim at accommodating diversity inside a group, particularly by enhancing getting to know each other in the beginning (Rekonen & Björklund 2016).

A certain level of psychological safety is needed for a team to work efficiently. Otherwise "groupthink" might occur, meaning that a team tend to reinforce its own dominant view, overwhelming the critical voices (Janis 1982). Team members should dare to say aloud their ideas, concerns and mistakes to be able to collaborate and learn in ways that enhance successful teamwork (Edmondson & Nembhard 2009, Harms 2015). A team leader is in an important role in calling for everybody's contributions and accepting fallibility (Edmondson & Nembhard 2009).

2.2 Teaching in project courses

2.2.1 The role of the teacher

The role of a teacher in student projects depends on how teacher-centered or student-centered approach is applied. Often the responsibility of actions shifts from a teacher to students as a course proceeds (Oksanen et al. 2011, Hmelo-Silver & Barrows 2006). If the aim is to acquire basic knowledge and skills, a teacher's role might be a traditional provider of information (Oksanen et al. 2011, Tambouris et al. 2012). As students in project courses act more or less on their own, a teacher should give some framework and guide the students to focus on the essential work to avoid disorientation (Oksanen et al. 2011). However, regardless of the approach, the teacher always has the ultimate responsibility on assessing the students (Berglund 2012). This might cause unwanted effects, if the students do not have courage to ask for help in a fear of showing lack of knowledge or if the teacher sticks to the role of evaluator and diminishes the role of a coach. When students do not have enough technical skills for building, some staff should be in hand to give support for example with machine tools.

In problem-based learning (PBL), the role of a teacher is commonly described as a facilitator (Hmelo-Silver & Barrows 2006, Tambouris et al. 2012). A teacher should not only understand the subject area but also strategies for learning and thinking (Hmelo-Silver & Barrows 2006). A facilitator monitors the groups' process, trying to see when it has stopped, is on a wrong track or when to give appropriate guidance (Sjöman 2014). One disadvantage of PBL is that proper facilitating requires a lot of teaching resources (Sjöman 2014). In shortage of teaching resources some other approach might be chosen or the quality of learning might drop.

2.2.2 Teaching methods

Traditionally, teaching methods for guiding student projects have been based on face-to-face teaching events. A common method is to arrange meetings with teams, preferably at least once in a week (Vesterinen 2003). These dialogues can help the students to examine perceptions and build relationships (Edmondson & Nembhard 2009) as well as be used in assessment.

A teacher can guide students in the right direction and enhance reflection through metacognitive questioning (Sjöman 2014). Thinking of understanding the role of different disciplines inside a team, a teacher might provoke discussion by asking how students' discipline can contribute to a specific problem or what it means to be a practitioner of some discipline (Richter & Paretti 2009). A facilitator's goals for the learning process might include keeping all the students involved in the learning process, increasing the students' self-confidence in independent learning (Hmelo-Silver & Barrows 2006), helping student's to reach their learning objectives and supporting deep learning (Vesterinen 2003).

The content of teaching related to both subject area and project work should be considered beforehand. A teacher can give some examples of professional work to establish standards and previous student work to define, what good quality looks like (Mergendoller & Thomas 2000). Giving explicit guidelines for working in teams and avoiding its pitfalls showed small improvement in the students' attitudes towards and skills in systematic teamwork (Bernier & Stenstrom 2016). Technical workshops can be organized to help students achieve required skills to run a project (Scott & Van der Merwe 2003). There are contradictory views on whether the teacher should define milestones for the project (Mergendoller & Thomas 2000) or let this task for the students and just create a schedule for teaching (Vesterinen 2003). Also different forms of reflection, feedback and assessment are valuable teaching methods in student projects (Vesterinen 2003).

A challenge for instruction is to make the student avoid wasting too much time in problems with a recognized solution (Kiviluoma et al. 2013). In many cases, the teacher does not know either an easy solution for a problem, but through discussion a detour or a new direction can be found.

2.2.3 Teaching students for independent learning

Special interest in this thesis is put on self-regulated learning (SRL). Zimmerman (2008) defines SRL as a learning approach that depends on the students' actions, as a degree which students control their learning process metacognitively, motivationally and behaviorally. Metacognition refers to knowledge of how learning occurs, choosing learning strategies and monitoring one's own learning process (DiDonato 2013). Motivation in SRL includes attitude towards finding and using information as well as self-efficacy (Schraw et al. 2006). Guiding students towards SRL approach might provide good results with reasonable teaching efforts in project courses. It can still be discussed whether it is worth it to teach students to be self-regulative, as this takes time and effort from substance content. Self-regulation can be seen as one essential learning outcome of university degrees. Utilizing SRL strategies also relate to good learning results (Auvinen 2015) and improvement in time management skills and mathematics learning (Zimmerman 2008). Thus, at least the SRL teaching methods are worth investigating.

There are several ways for a self-regulated learning approach. Self-regulatory strategies can be taught and practiced explicitly with directed actions, or teaching methods that support self-regulation can be used indirectly and suppose students develop SRL skills at the same (Paris & Paris 2001). Explicitly explaining the SRL approach helps students to understand the chosen methods, engages students in maintaining skills and might be associated with higher academic performance (Kistner et al. 2010). Bannert et al. (2009) state that especially when students lack metacognitive skills, SRL methods should be taught directly. Problem-based learning itself supports SRL approach as it gives responsibility of decisions to students (Paris & Paris 2001).

The core principles of SRL include getting to know oneself as a learner and managing own studying including time and goals (Paris & Paris 2001). Self-regulation can be promoted with assessments, feedback, discussions and teaching learning strategies (Paris & Paris 2001). In online courses, SRL teaching efforts might include facilitating goal setting, supporting students' reviewing strategies and automating online assessments (Anderton 2006). Auvinen (2015) supported self-regulated learning in computer science education with automated achievement badges and visualizations of the students' progress compared with previous years' students. Multiple self-report questionnaires to evaluate the SRL skills have been developed (Table 2). It is also possible to use traces of online activities to assess the level of self-regulation, however, these might not be congruent with self-reports (Zimmerman 2008).

Table 2. Some sample of different SRL self-report questionnaires

SRL questionnaire	Acronym	Developer
Motivated Strategies for Learning Questionnaire	MLSQ	Duncan, McKeachie 2005
Learning and Study Strategies Inventory	LASSI	Weinstein et al. 1987
Self-Regulated Learning Interview Scale	SRLIS	Zimmerman, Martinez-Pons 1988
Online Self-Regulated Learning Questionnaire	OSLQ	Barnard et al. 2008
Self-Regulation of Learning Self-Report Scale	SRL-SRS	Toering et al. 2012

An essential concept related to self-regulated learning is called scaffolding. The following explanation is adopted from the quality work of Puntambekar and Hubscher (2005). Historically, scaffolding has been seen as the actions of an expert to support an individual to complete a task he or she could not do by him or herself. More recently, scaffolding is seen as a tool that does the same trick, without an expert monitoring the process all the time. The zone of proximal development (ZPD) is defined as the zone that a student can reach with the help of more capable people (Vygotsky 1980). Well-organized scaffolding expands ZPD and the student can learn more effectively. As the ultimate goal of teaching is to educate people that, in addition to possess a pile of knowledge, can manage tasks independently, scaffolding must be faded away at some point. Teaching efforts should be planned so that students internalize the processes, so that in the end there is no need for external scaffolding.

Scaffolding can be used for different goals of learning. Firstly, Azevedo et al. (2005) evaluated three scaffolding conditions for knowledge building in a hypermedia SRL environment.

The research concluded that scaffolding must be adaptive to the students' progress in order to be effective, a fixed listing of sub-goals for a task helped students to gain knowledge as much as not scaffolding the progression at all. Secondly, Molenaar et al. (2014) investigated structuring and problematizing scaffolds' effect on metacognitive interaction inside a student group. They defined structuring scaffolds as telling how things should be, whereas problematizing scaffolds took the form of questioning students why and how things should be. They found out that both scaffolding supported metacognitive interaction inside a group, problematizing scaffolds being the more efficient from the two. Lastly, scaffolding can be utilized to help students becoming self-regulated learners as discussed above.

Teaching style should be adjusted to a student's level of independency in learning and the substance pre-knowledge. Grow (1991) presents that the severest mismatches occur when highly self-directed learners meet authoritarian teachers and when delegating teachers meet teacher dependent learners. A teacher's task turns more complex, if the background of different individuals is to be measured and taken into account with targeted teaching methods. Also, even highly self-directed learners might prefer an authoritarian teaching style, if they do not have internal motivation for learning something they still have to learn (Grow 1991).

2.3 Learning in projects

In projects, people always learn something about the subject and something about how projects should be run. In Cobb et al. (2008), product development course alumni cited as the main learning outcomes, in addition to an increase in substance knowledge, to work in multidisciplinary teams, brainstorming and concept generation and analyzing user needs. Students involved in project-based learning are motivated by it and have improved skills in communication and putting knowledge in practice (Scott & Van der Merwe 2003). However, they might have difficulties in understanding the fundamental concepts (Scott & Van der Merwe 2003).

A project team sets a specific environment for learning. A team supports learning by enabling questioning, giving feedback, experimenting, reflecting on results and discussing errors or unexpected outcomes of actions (Edmondson 1999). Team learning can be more effective than individual learning because of the diversity of knowledge, experiences, and perspectives are brought together (Hill et al. 2014). Expertise of the members can be utilized for the project and be learned by the other members. Team participants with better self-regulatory skills may help others to develop their SRL skills (DiDonato 2013). SRL skills help individual learning in a team, even though they might not otherwise improve the performance of a team (Harms 2015). The level of how well a team can learn could be measured with a team learning behavior scale (Edmondson 1999), showing it could affect positively a team's functioning.

Many things challenge the learning experience in project courses. An unsystematic progression of the project, unclear instructions and communication problems may hinder the student involvement (Vesterinen 2003). Shared responsibility in a team might lead to social loafing (Vesterinen 2003, Kayes et al. 2005). This challenge can be tackled by peer-assessing individual contributions to the project (Johnston & Miles 2004). Edmondson and Nebhard (2009) suggest that actually challenges occurring in projects force to learn essential issues to run projects. This does not mean that learning should not be supported explicitly. Without planned teaching interventions students might not engage in the learning process (Kayes et al. 2005). At least a shared sense of a team's purpose and learning to know team members are essential requirements for a functioning team (Kayes et al. 2005).

2.4 Assessment in project work

Thinking of a student project, the main purpose of assessment is to give a student a grade based on his or her performance. This is called summative assessment (Vasilevskaya et al. 2014). The other main form of assessment, called formative assessment, is meant to give student feedback to improve learning and working also during a course (Hunaiti et al. 2010). Formative feedback can be seen also to improve student's motivation and building self-image (Vesterinen 2003). Other desired positive outcomes of assessment include greater responsibility and awareness on learning and continuing efforts along a course (Paris & Paris 2001).

The main principle of aligned teaching is that teaching methods and assessment criteria should be aligned with learning objectives (Biggs 1996). Learning objectives in projects might include adopting skills and knowledge in group, project and interdisciplinary working as well as in the subject area. The quality of a project is composed not only by its final output but also by its progression (Artto et al. 2011). Thus, assessing only the end product is not recommended, but frequent summative and formative assessment should be conducted also during a project (Barron & Darling-Hammond 2008, Vasilevskaya et al. 2014). Table 3 gives a short literature review for suggested assessment criteria for project work, however, it should be kept in mind that criteria for a course should always be decided content-wise.

It is a necessity that the assessment criteria are definite right from the beginning of a course. A rubric includes a set of guidelines for giving scores (Scott & Van der Merwe 2003). It tells, what is being assessed, at what scale and what is required to reach some level (Scott & Van der Merwe 2003). Students easily target just to fulfill the grading criteria. Thus the content to be assessed should not be narrower than the teaching content. A teacher can also think that only publishing the assessment criteria without specific measures could help students to focus on learning. Vasilevskaya et al (2014) present a method where teachers define the grading criteria and the student teams must decide a goal based on the criteria in the beginning of a course. Then, the students can use the criteria as a checklist for their project.

Student-oriented methods target to assess either oneself or peers. Learning diaries, portfolios and student questionnaires are examples of self-assessment methods. Self-assessment has provoked contradictory feelings in the literature. Vasilevskaya et al. (2014) had experienced self-assessment as a useful tool for self-reflection, improved working of students and for understanding individual student performance. Their sample students were in the other opinion, as only 12 % of the students confirmed that self-assessment helped them to learn and 37 % did not consider it as a reflection method as it was used for grading.

Table 3. Assessment criteria for interdisciplinary project work.

Learning object	Criteria	Source
Interdisciplinary working	Work is grounded to the theories of different disciplines	(Mansilla & Duraisingh 2007)
Interdisciplinary working, critical thinking	Critical awareness: the limitations and possibilities of disciplines are taken into account in the aim of the work and in the end result	Mansilla, Duraisingh (2007)
Interdisciplinary working	The work shows development in understanding by showing a solution that could be achieved only by integration of disciplines	Mansilla, Duraisingh (2007), (Richter & Paretti 2009)
Interdisciplinary working	Value contributions from multiple fields	(Richter & Paretti 2009)
Project working, subject area	Documentation is well done and clear use of evidence	(Barron & Darling-Hammond 2008)
Critical thinking	Accuracy of information	(Barron & Darling-Hammond 2008)
Critical thinking	Evaluation of competing views	(Barron & Darling-Hammond 2008)
Presentations	Development of a clear argument	(Barron & Darling-Hammond 2008)
Presentations	Attention to writing conventions	(Barron & Darling-Hammond 2008)
Group working	Collaboration	(Barron & Darling-Hammond 2008)
Project working	Evidence of the independent though and information gathering relevant to the research project	(Hunaiti et al. 2010)
Project working	Evidence of learning-by-doing and developing problem-solving skills	(Hunaiti et al. 2010)
Subject area	Evidence of acquiring solid and varied theoretical foundation coupled with practical experience	(Hunaiti et al. 2010)
Group working	Evidence of developing communication skills as well as building effective team relationship	(Hunaiti et al. 2010)
Group working	Internal working	(Vesterinen 2003)
Group working	External interaction	(Vesterinen 2003)

Schunk and Ertmer (2000) suggest that periodic self-evaluation supports achieving learning goals and high self-efficacy. Some evidence shows that self-assessment should not be used for summative assessment. Johnston and Miles (2004) found that there was no correlation between self-assessments and marks awarded by teachers. On the contrary, peer-assessments were in line with teacher marks in their study. Willey and Gardner (2009) argue that including self-assessment in calculating contribution factors gives a more reliable summative assessment and forces students to compare their own work to team members' work. Peer-assessments also work as formative assessment as they help students to understand their roles and actions in a group. Teacher-oriented assessment is conducted by teachers. As an example method, the teachers of a course can grade all groups first individually and afterwards discuss the grading among colleagues (Vasilevskaya et al. 2014).

Division of tasks in a project commonly ends up in duties with varying level of complexity, which might be wanted to take into account in assessment. Both individual and group grading methods should be utilized to put value on individual contributions and group performance (Mergendoller & Thomas 2000, Vasilevskaya et al. 2014, Johnston & Miles 2004). A typical group assessment is a final feedback report with a grading table including different assessment criteria and closing comments (Vasilevskaya et al. 2014). Special individual student interviews can be conducted as individual assessments to find out personal actions. If there were some common learning goals, they should be tested with individual assignments.

2.5 Feedback in project work

Feedback is seen as part of formative assessment dealt in the last chapter. The aim of feedback is to give information and suggestions to the students' actions for their improvement, preferably just-in-time (Brookhart 2008). It increases the students' self-efficacy and eager to self-assess (Vesterinen 2003). The method of providing feedback should be chosen carefully to avoid misunderstandings. Students might think negative feedback is person-related or that it tells they are stupid and cannot learn. One difficulty for students is that they have to address contradictory feedback from peers and teachers, and not so that they only take into account the most positive feedback, rejecting the negative one (Vesterinen 2003).

Feedback in projects can be divided into instructor-oriented and peer-oriented methods. Vasilevskaya et al. (2014) present that oral feedback is commonly provided in meetings for teachers and students. They also present a method called on-demand artifact feedback, where students can ask for oral or written feedback to improve the quality of their artifacts. This might help students to see the quality of their work in a broader perspective. The third feedback method they propose is called retrospective. In those sessions, student teams discuss their performance after every iteration round of the project. They also highlight that peer-feedback can work effectively in learning from each other in a group. Peer-feedback can also help each group member to get aware of the group's perception of his or her participation and commitment (Scott & Van der Merwe 2003). Rekonen (2016) presents a systematic feedback session method, called "I like, I wish", emphasizing psychological safety. It can be used in projects to create open communication inside a group, to clarify faulty assumptions and to allocate time in proper feedback in a hurry project. The idea of the method is that every member writes and speaks out what he or she likes in others, in team and in him or herself, and what he or she hopes from them.

2.6 Project execution

Project execution can be divided into phases. For simplicity, a sequential project process is considered. Especially when thinking of design projects, also other ways to advance are available, for example an iterative process (De Blois et al. 2016) or a cycle process (Sjöman 2014). According to Artto et al. (2011), the phases of a project can be defined as project start and specification, planning, implementation, control and closing (Figure 1).

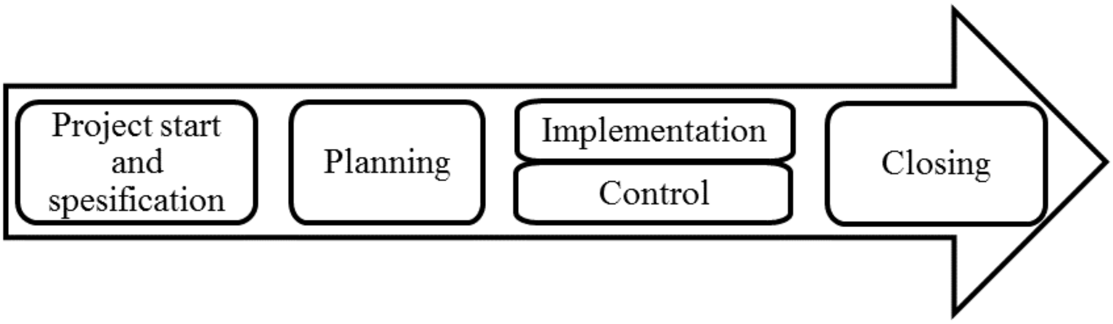


Figure 1. Phases of project execution (Artto et al. 2011).

Project start and specification include getting to known with the group, creating team spirit, sharing expectations and creating a preliminary project plan. Usually the motivation of the group is high but the effectiveness of the group is low. As an example, agreeing on the common rules and working methods of the group as well as defining the goal, schedule and budget are written in the project plan. (Artto et al. 2011)

During the planning phase, the implementation of the project gets its form. In a product development project, a technically feasible and economically sensible design is created (Artto et al. 2011). At the same time, the group should start adopting working methods including the communication and documentation habits. The specification of the content of the project is discussed with the customer (Artto et al. 2011). A teacher could correspond to a customer in a university course context. The project group starts creating ideas for the implementation. They make feasibility study on their ideas. Possibly they make prototypes on some ideas. Usually, some systematic method is used to make decisions on the concept to be implemented. More specific planning is made for the chosen concept.

According to Artto et al. (2011), implementation means addressing resources to the right tasks at the right time in terms of targets and documenting the work appropriately. The actual content of the tasks is prescribed and the needed resources are acquired in the implementation phase (Artto et al. 2011). Then, the product is created. Artto et al. (2011) state that a control routine should be run parallel to the implementation phase. This means developing the product based on measures, feedback and work results.

A closing phase ends a project. The documents are finalized and a closing and feedback meeting is held (Artto et al. 2011). In student projects the results are presented and learning is reflected.

Commonly, the first challenge a project team faces is getting to know each other and building team spirit. It is possible to organize actions or events to support this development path. Another challenge is updating the norms of working when changing from a phase to another inside a project (Rekonen & Björklund 2016). Different phases require different kinds of actions. It should be clear in all phases, how the team works and what is the role of each team member. At the end of a student project, especially if the time is running out, the project team might concentrate only on finalizing a physical prototype of the project (Rekonen & Björklund 2016), neglecting other actions that belong to the end of the project.

2.7 Project management

The areas of project management relevant to student projects consists of managing the scope, time, costs, procurements, risks, quality, communication, information and integration. Scope management means dividing and sharing tasks and keeping the extent of the project in control. One challenge in costs management is to avoid feature creep. This means that designers add unnecessary features to the end product, which only makes the product more expensive (Artto et al. 2011). Challenges of procurement include for example long ordering times and ordering wrong parts. Other parts of project management are looked at more in detail in the following chapters.

2.7.1 Project manager

There are several possibilities for managing student projects. A teacher or an academic instructor can be in charge of giving students tasks. Often student groups are left to manage themselves. They might be asked or they might name a project manager among them. Otherwise the team members manage their work more or less independently. This is a risk, as a leader in a team is shown to improve the team's performance (Mumford et al. 2002).

Mumford et al. (2002) suggest that creative leadership should facilitate idea generation, idea structuring and idea promotion. Applying this to a student project, the project manager should aim at encouraging teammates for creative work, handle the content of the project and its tasks and communicate the needs and aims of the team with the course staff. The greatest part of project manager actions might focus on managing tasks in the expense of managing humans in a student project (Rekonen & Björklund 2016). Thinking of the result of the project, this might be reasoned. Teams with good task management are more likely to end up with good project results (Weimann et al. 2013). Yet, challenges related to people management like having enough time for informal conversations for better team spirit and being unsatisfied for group members and their participation have been recorded (Rekonen & Björklund 2016). Also the role of the project manager as a technical expert might be a challenge if he or she neglects the leader responsibilities (Rekonen & Björklund 2016).

2.7.2 Time management

Time management means scheduling the project. The duration of the tasks should be estimated, which is a challenge if there is no previous experience on similar projects (Artto et al. 2011). If this is the case, the documentation of previous similar projects can be utilized for the estimations (Artto et al. 2011). Also the order in which the tasks are done should be planned. For example, a Gantt chart might help taking into account the order of consecutive tasks and setting milestones for a project (Figure 2) (Artto et al. 2011, Hunaiti et al. 2010). Two strategies are possible for managing time. The bottom-up strategy exploits the duration of different tasks for planning the whole schedule while the top-down method divides the given timeframe of the project to certain milestones (Artto et al. 2011).

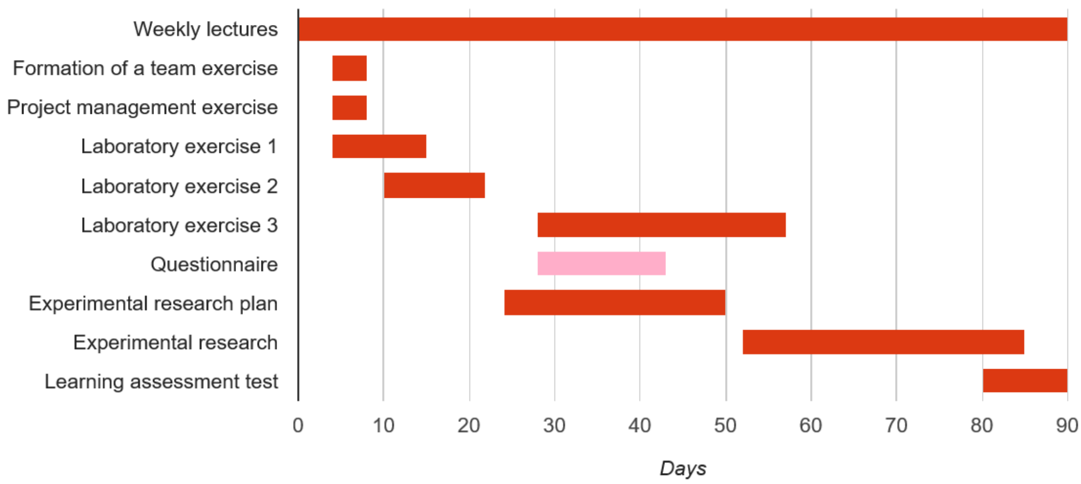


Figure 2. A Gantt-chart showing the basic timeline of the Mechanical and Structural Engineering Laboratory course presented in Chapter 3.1.2.

Some arisen challenges in student projects related to time management include bad estimates on how long some task will take and the lagging completion of different sub-tasks leading to overburdening with tasks at the end of the project (Rekonen & Björklund 2016).

2.7.3 Communication management

The aim of communication management is to establish communication channels and routines for enabling the smooth interaction and share of knowledge both inside a project team and with external parties. Communication can be formal, informal, written and oral (Artto et al. 2011). Also meetings and discussions are part of communication (Artto et al. 2011). Normally the agenda and the schedule of a meeting are on the chairman's response and the invitations and writing the minutes on the secretary's response (Artto et al. 2011). In a student project, these roles should be confirmed to avoid misconceptions.

Communication is no doubt challenging. Everybody should receive all the necessary information at the right time without drowning in too much information. People from different disciplines or cultures might have difficulties understanding each other (Artto et al. 2011). Communication should be fast and effective inside a project team.

2.7.4 Information management – Documentation

Information management means creating, perceiving and sharing information, documentation and knowledge. A project group agrees on the methods, tools and formats of information management. Tools are used for producing text (e.g. Word), CAD files (e.g. PTC Creo) or images (e.g. Adobe illustrator). Documentation methods include the idea on how documentation is stored. Is some cloud service (e.g. Google Drive) or PLM software (e.g. PTC Windchill) used? The group should also decide how and in which format internal and external documentation is created. PDFs are easy to read for some external partner, but the text is difficult to modify and does not provide much interaction that could be utilized for example in some documentation in a Web page. Documentation can support communication and quality management. It also makes possible to learn and take advantage of the development work for the following projects. (Artto et al. 2011)

It should be kept in mind that information is created for different purposes: for example documentation for the customer includes the description of the properties of the product and a user manual, documentation for the project's own organization all the created plans, materials and codes and documentation for the internal use of the project group division and current stage of each task. In a student project, a customer could mean also the teacher and the forthcoming student projects can be thought as the project's own organization. Stettina et al. (2012) also show that documentation should not be done within just one session, as iterative documentation improves the quality of documentation. They add that even though teams felt iterative documentation as a burden, the resulted knowledge sharing was perceived as important.

Portfolios and learning diaries are common methods used for the documentation of learning. A portfolio contains material that has been acquired and created during a project (Vesterinen 2003). Learning diaries describe the actions and learning occurring during a project (Vesterinen 2003). They both enhance student's reflection and can be used in the assessment of individuals (Vesterinen 2003, Godfrey 2014).

2.8 Online tools for projects

Here some online tools and methods are presented. The aim is to find out, how learning and project management can be improved or done more effectively with online tools.

2.8.1 Teaching

When teaching project courses, it is not reasonable to create a single tool for handling every relevant area, but various software tool should be provided for students, (Tambouris et al. 2012, Weimann et al. 2013). This is also because such a tool could be easily outdated, as the technologies keep on developing. A challenge for online tools is to turn them to student-oriented. It would enable teaching interventions suited for each individual. Tambouris et al. (2012) found that the task was so complex that they decided to keep the teacher-oriented approach in the task giving in an online PBL environment.

Yilmaz and Tuncalp (2011) investigated interactive teaching material created with Adobe Captivate and Adobe Flash. They found out that students appreciated videos and animations for helping understanding and instant quizzes following learning content for preparing for final examination. Software should allow adaptive support for individual backgrounds and learning skills, diagnose proceeding and calibrate support (Puntambekar & Hubscher 2005). Karakostas et al. (2012) utilized a tool for scaffolding knowledge building that was capable of giving suggestions to help students to learn essential concepts. Model-It tool was able to show examples and hints what to do next when needed (Puntambekar & Hubscher 2005). A Metacognitive online scaffolding tool can be used to support the process of group working (Kwon et al. 2013).

2.8.2 Feedback

Willey and Gardner (2009) investigated an online peer feedback tool. They had found out that if the feedback tool was only used for assessing peer effort for a group project, students found the tool useful for avoiding free-riding in a project. As the authors had an ambitious goal for the tool to also give students feedback on their personal development, they added features in which students not only assisted their peers' efforts but also the quality of their contributions. Their trials show that the tool assisted in improving student's engagement, learning from peers and in the collection and distribution of feedback. They aim to utilize this peer-feedback to guide assessment.

An online peer-feedback tool might encourage students to give more critical feedback, at least when given anonymously. Still, students might also be gentle to each other, and not report deviations in time usage, if there is not (grade) pressure for that. Compared with face-to-face feedback as "I like, I wish" method discussed in a previous chapter, online feedback tool does not require as much teacher involvement. As Willey and Gardner (2009) point out, just a utilization of a technical tool does not substitute good assessment. Thus, technical feedback tools should be developed carefully and a teacher should monitor the quality of the feedback given in a tool.

2.8.3 Project management

Project management can be supported with dedicated project management software (PMS) or by applying other common software. PMS might be too heavy for student purposes. Weimann et al. (2013) report a student's experience with Microsoft Project: "It was a waste of time, but we also didn't really know how to use it." Another approach would be that a group has a simple written documentation repository for storing and maintaining the project management issues. This method would be free, but it might be more difficult for the overall management of the project as well. Easy, affordable and good enough tools, like Microsoft Excel, are valuable for students (Li et al. 2012). Rather than giving some screen captures of examples, a teacher should provide students with for example Excel sheets, so that the students are able to get their hands in to the examples.

The crucial areas to control in a project include time and task management. These can be supported with tools that are included at least in most commercial PMS (Weimann et al. 2013, Tan & Jones 2008). A project team might want to have a common calendar to see meeting times and deadlines (Weimann et al. 2013). For example, free-to-use Google Calendar can be utilized for this purpose. Software tools can ease task management by showing the state of each task, collecting data on time spent on tasks (Weimann et al. 2013) and visualizing how much each group member has contributed (van Leeuwen et al. 2015).

2.8.4 Communication

Online communication tools can be divided into synchronous and asynchronous. Synchronous tools include instant messaging software like WhatsApp and remote meeting software like Skype. If team members can have a physical meeting, it is often preferred to a remote one. Asynchronous tools include discussion forums and e-mails.

Asynchronous communication allows time for thinking and reacting (Vuopala et al. 2016). It enables peer-learning where more skillful students contribute by raising important issues, pointing to resources, and providing clarifications whereas other students bring up questions and ask for clarifications (Puntambekar & Hubscher 2005). Synchronous discussions are needed for rapid information sharing inside a group. Synchronous discussions are more informal and provide less opportunities for reflection than asynchronous ones (Vuopala et al. 2016). If a teacher is supposed to attend communication, synchronous communication draws more effort than an asynchronous one (van Leeuwen et al. 2015). Students are able to choose the communication tools by themselves. However, Vuopala et al. (2016) suggest that a collaborative script provided by a teacher might enable more versatile communication skills of students.

2.8.5 Documentation

As mentioned before, a project group produces documentation for internal and external use. The aim of online external documentation is to publish the achievements of a project. In student projects, this could mean included parts, connections, software as well as using and building instructions. This publishing can be done in a project's own Web page, a Wiki-page or dedicated do-it-yourself project sites like Instructables.

For internal sharing and storing purposes a project team might want to have an online repository (Weimann et al. 2013). It can be part of a PMS or located in organization's network drive, in Google Drive or Microsoft OneDrive in the internet. A team can store documents like meeting minutes and invoices there, images and presentation slides. It is recommended to establish a version control routine, either by hand or automatically by the tool for keeping documentation versions in order (Tan & Jones 2008). The advantage of online communication is that written messages are automatically preserved, to look back when needed.

2.8.6 Challenges of software in project courses

A challenge that is always present with new technology is that something will not work as expected. Lintilä and Kiviluoma (2016) report that compatibility problems with computers and software in an engineering laboratory course lead to waste of time and frustration of students. If possible, all the software should be tested well beforehand. Use of software in courses is characterized by a lot of pre-arrangements and design from a teacher. Also concentrating too much on a tool development might lead the focus away from the intended teaching approach. As Willey and Gardner (2009) put it, a technical tool is not a substitute for good teaching design. When designing the e-learning part of a course, learning objectives should always be kept in mind. Vuopala et al. (2016) suggest utilizing a collaborative script to enhance the online communication skills of students. This should be done only if the improvement of online communication skills is seen as an important learning objective. In their research, Kwon et al. (2013) showed that the students who did not utilize actively an online metacognitive group process tool actually performed a little better than the students who used the tool actively. This result suggests that active utilization of some online tool does necessary not improve the studying performance. On the contrary, it might take time from learning more important concepts.

Self-regulated learning and team-regulated learning in projects increases the distance from a teacher to the situations where learning occurs. The introduction of online tools widens this gap even further. This challenge easily leads to bad studying habits. When there is no clearly allocated time for some studying tasks, students might want to execute them as fast as possible, neglecting the learning process. It may also lead to unnecessary procrastination, namely returning submissions at the last minute (Auvinen 2015). Students might utilize the trial-and-error method instead of careful thinking when doing automatically assessed exercises (Auvinen 2015). For most tasks, the use of one medium alone is not sufficient to achieve ideal performance (Weimann et al. 2013). Learning to use multiple tools is itself demanding for a student. A question is, at which extent students are let to choose the tools they use and to which extent teachers choose them. Weimann et al. (2013) discuss that team member satisfaction and team performance is highly related to how well team is able to choose tools according to the team members' individual needs and preferences.

3 Development of online methods for projects

3.1 Introduction to the courses

The following chapters present the online methods that were developed and tested. Two courses in Aalto University have been utilized for the research (Table 4). A survey on the challenges of projects was held in ARTS-ENG-Project. The developed methods were tested in the Mechanical and Structural Engineering Laboratory course. The research is based on questionnaires for students' perceived experiences.

Table 4. Introduction of the courses used in this research.

	ARTS-ENG-Project	Mechanical and Structural Engineering Laboratory
Chapter	3.2	3.3-3.8
Number of students	156	61
Intended study year	1	2 to 3
Number of ECTS	5	5
Timing of the course	4/12/2016-5/19/2016	9/16/2016-12/16/2016
Questionnaire answer time	5/13/2016-5/20/2016	10/14/2016-10/28/2016
Number of answers	111	46

3.1.1 ARTS-ENG-Project

In ARTS-ENG-Project course, teams with about eight students from different engineering disciplines and architecture are introduced to team and project working. The course is scheduled to the end of the first study year. The teaching is based on weekly group meetings with the teachers and weekly reports. As a result of the projects, students develop concepts that are presented in a final gala. The project topics varied from an intelligent thermostat to a mobile application to find apartments.

3.1.2 Mechanical and Structural Engineering Laboratory

In the other chapters, online teaching methods were developed and tested in Mechanical and Structural Engineering Laboratory course. If not otherwise mentioned, the methods are created in the Moodle-based learning management system of Aalto University called *MyCourses*.

The goal of the course is to teach basics of measurements and laboratory working. Figure 2 in Chapter 2.7.2 shows the structure of the course. The students were divided into groups of two to four people by their own choice or teacher's allocation. In the beginning of the course, the students were asked to run a grouping and a project management task to help their team work get started. The tasks were implemented in *MyCourses* as problematizing scaffolds so that the students had to read through instructions and give some answers.

Three laboratory exercises and an experimental research project were made in teams. The laboratory exercises included a pre-laboratory exercise, where the students were asked about the measurement system and to prepare a LabVIEW file based on instructions. Figure 3 shows the equipment used in the two first laboratory exercises. Students were given the wiring diagrams and instructions on how to run the experiments. The analysis of the measurements was done with MATLAB. MATLAB instructions were given as PDF documents and .m scripts in the 1st laboratory and as .mlx Live Scripts in the 2nd laboratory.

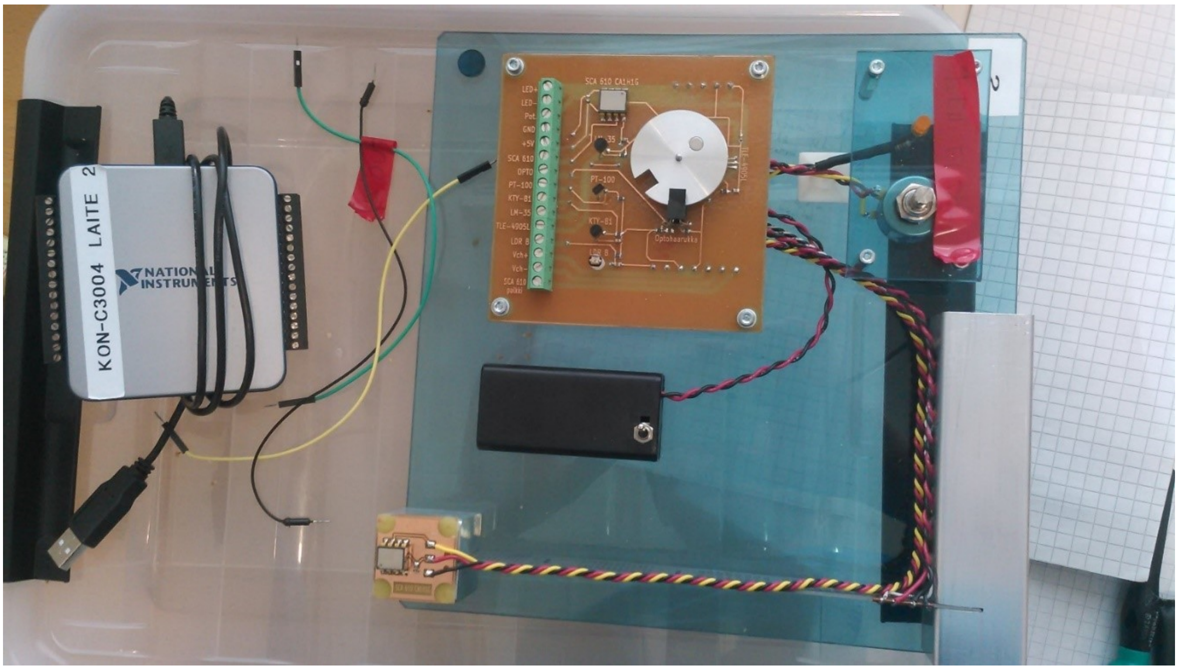


Figure 3. The equipment used in the 1st and 2nd laboratory exercises.

In the 3rd laboratory exercise, the students were given somewhat more complicated measurement systems and examples of the measurements that the previous years' students have done with the equipment. The material for the 3rd laboratory exercise contained also instructions for using the equipment as a Web page with both written and video material and a quiz. The students had to decide themselves a meaningful measurement task and run it. During the laboratory exercises, there were always four groups and a teaching assistant present.

To test the developed methods, students were asked to fill a questionnaire halfway through the course. By the time answering the questionnaire, students had already done two first laboratory exercises and read preliminary material for the 3rd and last exercise. Effectiveness of different methods is estimated by a perceived effectiveness factor (PEF) defined by

$$PEF = \frac{Perceived\ benefit\ of a\ method}{Perceived\ use\ of\ time\ for\ a\ method}. \tag{1}$$

PEF for each method is calculated in the chapter they are discussed. The perceived effectiveness factor gives some insight on what students think of the different methods compared to each other. The average of four different PEF values is 1.04.

3.2 Challenges in projects

As part of the final questionnaire of the year ARTS-ENG-Project course, students' perceptions on the difficulties in team projects were asked (Figure 4). Figure 4 shows that students were mostly concerned about the openness of the task definition in a project and difficulties in getting started, time management and division of tasks. On the other hand, students did not consider the relationships between team members such a problem.

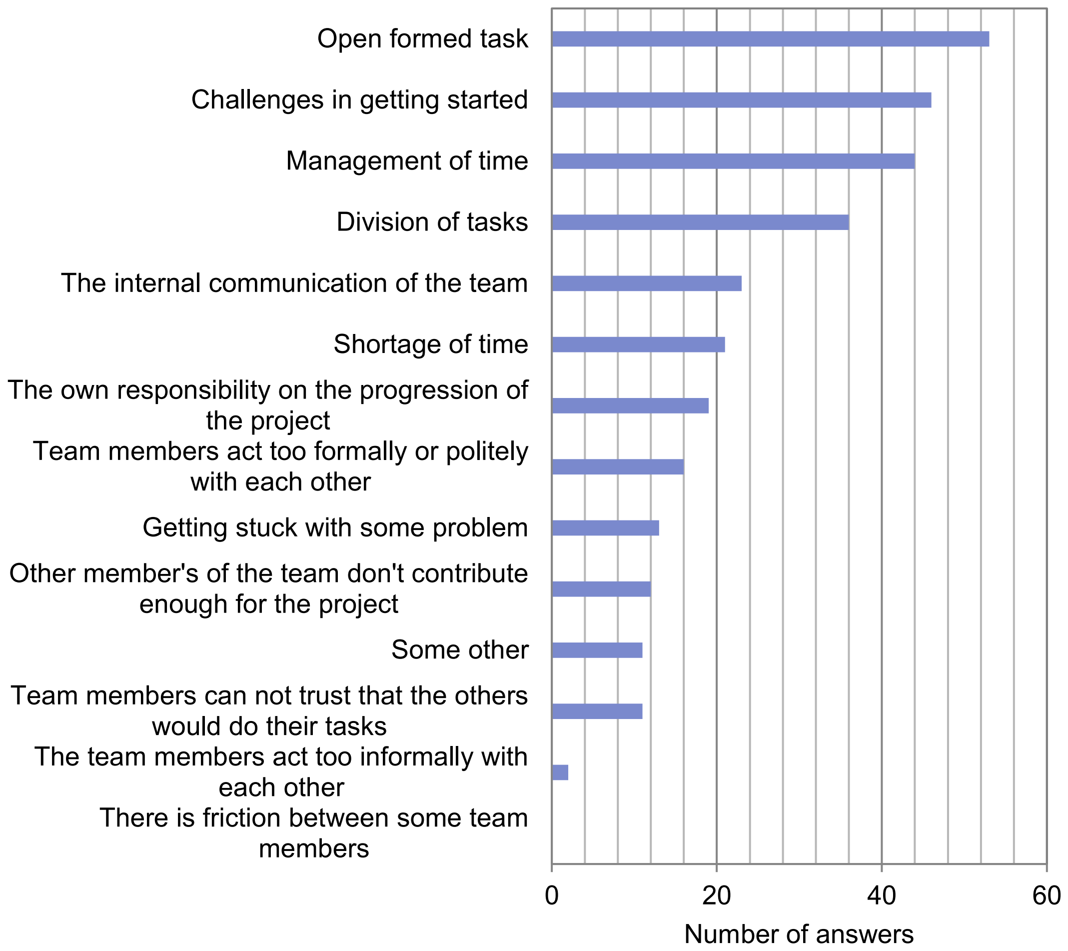


Figure 4. Name 2 to 5 biggest challenges that may occur in a project with a team. You can answer based on this course or on some other project.

The attitude towards open formed task definition might result from a fact that the students are used to closed-form questions in high-school and other university studies. This challenge might be tackled by giving practical examples for good project topics. If the objective is to make the students ponder on meaningful topics, supportive methods for creating and assessing ideas should be provided. These might include for example brainstorming or 635 methods.

Difficulties in getting started might result from the initial fussing of the project. People do not know each other and what they should do next yet. They might feel also that they are not in a hurry, so why to rush. This also relates to the challenge of time management. Teachers should provide clear instructions on the first tasks a group should do and mid-term goals. Later on, the working should start running more on its own pace. Students can be supported also by asking them to schedule and keep up a calendar. The students should allocate themselves a required amount of time for the project right from the beginning.

Dividing tasks might cause problems if the group does not know what the possible tasks to be done are. In the verbal comments, some students raised the issues when either some people are unwilling to take responsibility or some people take the majority of responsibility, leaving not much for the others to do. One way to help project teams is to give good examples on how effective teams have divided their tasks. Also asking students to write down their contribution to the project might ease the uneven share of responsibilities.

3.3 Formation of a team

After the students in the laboratory course had formed their team, they were asked to perform a grouping task. The idea was that a team would gather to a place to discuss five different aspects, including getting to know each other, responsibilities, communication, working methods and goals of the team (Appendix 1). The task was implemented with *Lesson*-tool in MyCourses. The students first had to read a short introduction and then write down the main issues that arouse from their discussion.

In figures 5 to 7, students' perceptions of the formation of a team exercise are shown. In addition to showing results from all students (Figure 5), the students were grouped by how well they knew their team members before the course. Students, who said that they knew their team members badly or very badly were in one group (Figure 6) and students, who knew their team members well or very well were in another (Figure 7) The way the students conducted the exercise was asked separately (Figure 8).

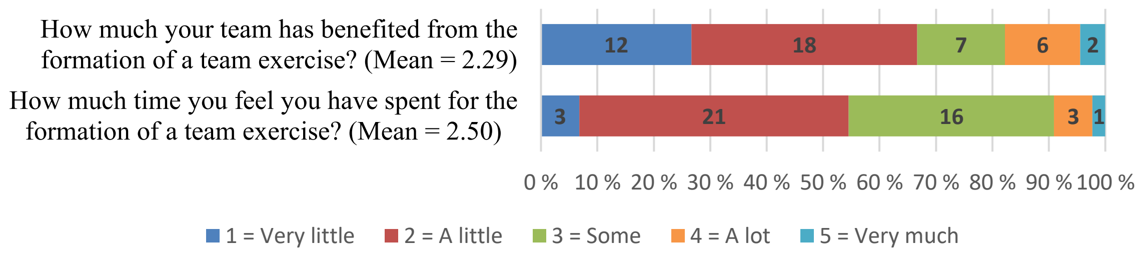


Figure 5. Students' experiences from the formation of a team exercise. All students.

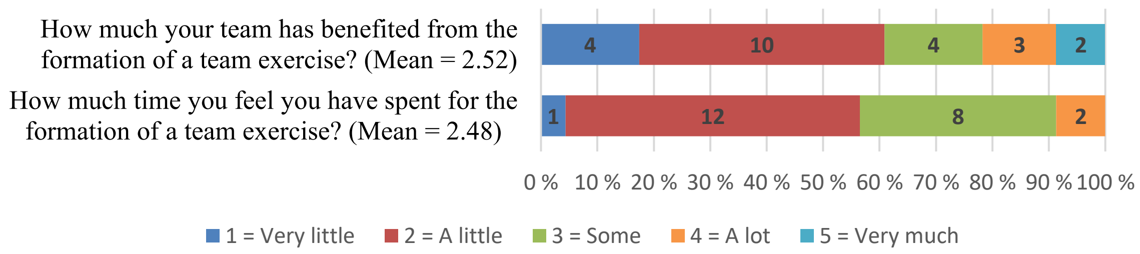


Figure 6. Students' experiences from the formation of a team exercise. Students who knew poorly their team beforehand.

Figures 6 and 7 show that the students who did not know their group beforehand appreciated more and spent more time with the grouping exercise than the students who already knew each other. The formation of a group exercise gets an overall PEF of 0.92.

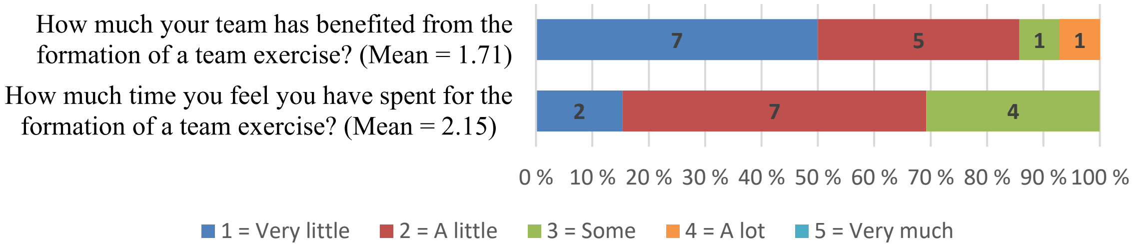


Figure 7. Students' experiences from the formation of a team exercise. Students who knew well their team beforehand.

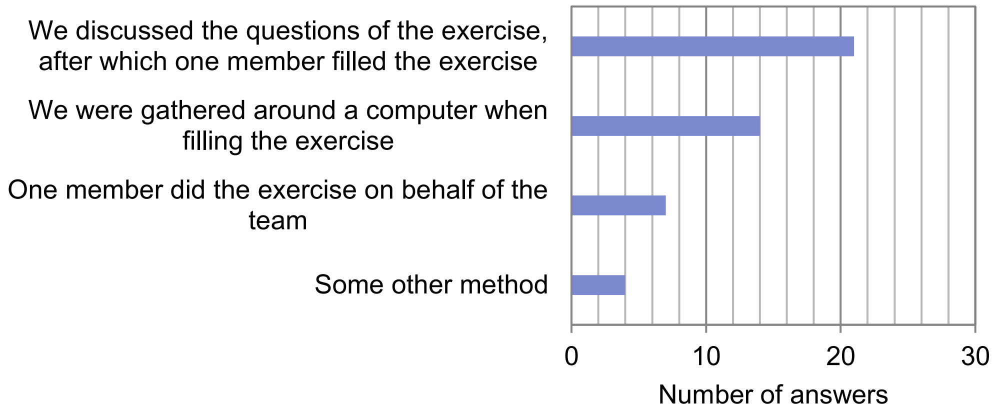


Figure 8. How team members were involved in the formation of a team exercise.

Figure 8 shows some challenges related to the used method. In some cases, one team member filled the exercise without consulting the other team members. Only the team member who had filled the answers to the exercise could see these answers. Should the exercise be done face-to-face or online was not instructed. In the next iteration, instructions for both possibilities as well as one document instruction and report should be made.

When discussing this exercise with the teachers of the Biology meets Mechatronics pilot, they found this exercise good and as something that should be done in every course with team working. Overall, the quality of the answers the students produced for the exercise were good.

3.4 Project management

A project management spreadsheet was created with Google Spreadsheet to support students' project management (Appendix 2). It included dividing a project into tasks, time management options with deadlines and allocated working days and hours, filling the readiness stage of the tasks and therefore calculating the readiness of the whole project and following team member's working hours and comparing this to the allocated ones. A Gantt chart, a state of the projects and tasks and a working hour diagrams were drawn to visualize the process. The project management spreadsheet could be used as a plain sheet so that the users would have to fill it by themselves. This time the teaching assistant filled the main tasks, their deadlines and expected working hours ready for the students.

The students were introduced to the project management spreadsheet and an online, free to use PMS Freedcamp in a couple of pages PDF-instruction (Appendix 3). The groups had to read the instructions and fill a questionnaire on how they are going to organize their project management, possibly by utilizing these introduced methods. The students could come up also with their own methods. The students were told that they would have to report each members' contribution to the project, and this is preferably to be done with the help of the used project management tool.

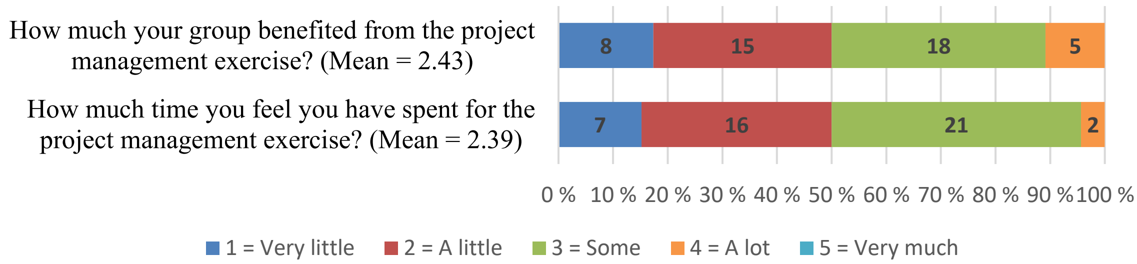


Figure 9. Students' experiences from the project management exercise.

From Figure 9 and Equation 1, a PEF of 1,02 is calculated for the project management exercise.

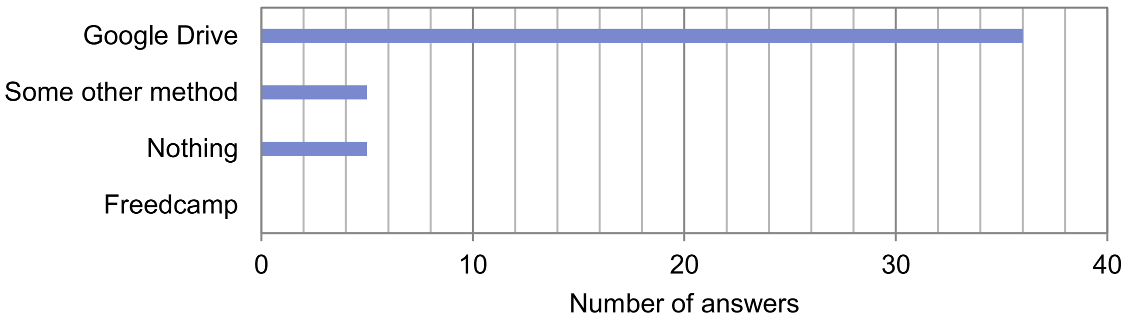


Figure 10. What tools your team has utilized for project management?

Figure 10 shows that most of the students utilized Google Drive as the main tool for their project management. However, when asking for each members' contribution to the 3rd laboratory exercise, only one group utilized the Project management spreadsheet as instructed. This implies that only a few groups actually utilized the given instructions for project management. The rest of the groups have managed without the instructed PMS methods, and doing project management exercises have been of no use. One explanation is that in Mechanical and Structural Engineering Laboratory course the project work is only a part of the 5 ECTS course, thus it might not need such a heavy project management method.

3.5 Documentation

The format of teaching instructions and student assignments was investigated. The first question was, what kind of documentation provides effective learning support, is easily adoptable, understandable and smoothly interfaced with engineering software. Students' preferences on the format of teaching material in laboratory exercise instructions, supporting material and instructions for writing MATLAB analysis were asked. The second research question aimed to find out, how students should create documentation so that it would be useful for the students of the next course implementation. The students were asked their thoughts on the material produced by the previous years' students.

For an open question on what instruction material should be like to promote learning and preparation for an exercise, the students answered that it should be clear, detailed, include pictures, videos and examples, leave space for student's own thinking, provide extra instructions for special needs and highlight the relevant issues in an exercise. The numerical results of the students' perception on documentation are shown in Figure 11, Figure 12 and Figure 13.

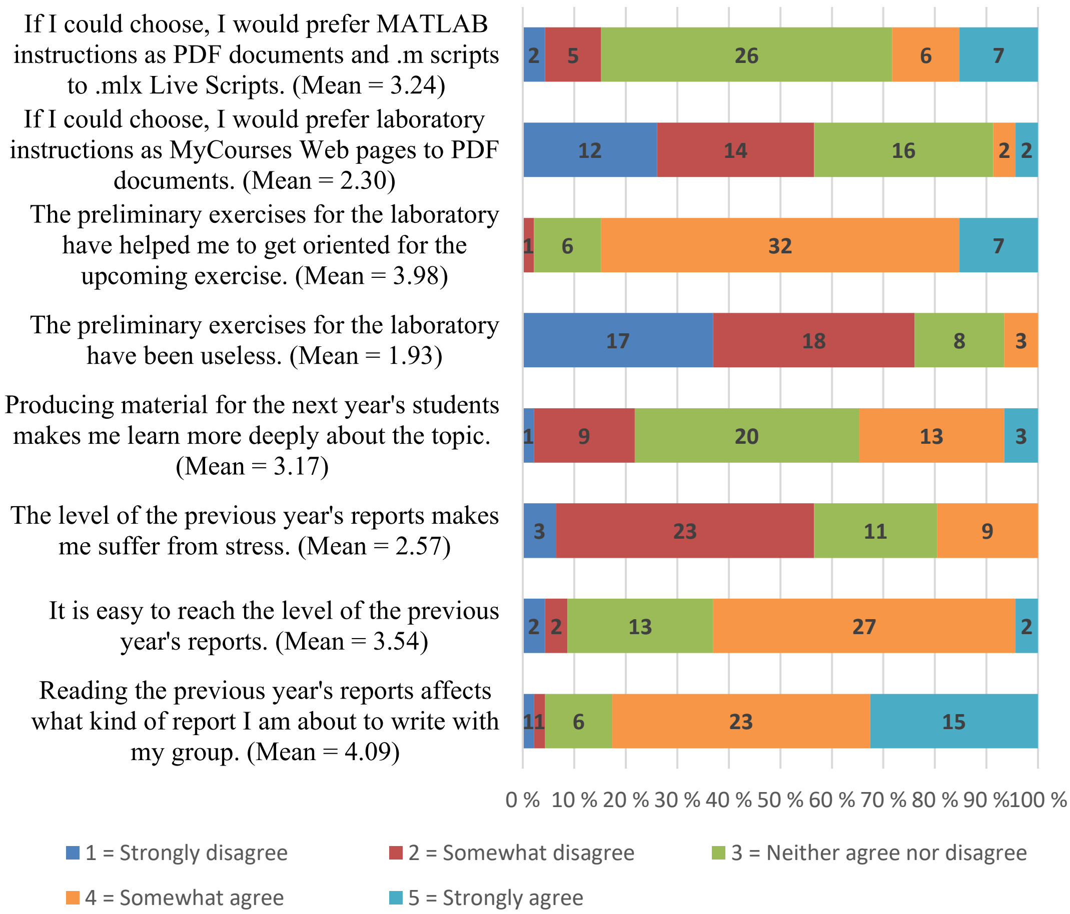


Figure 11. Answer the following claims related to documentation.

Figure 11 reveals that providing previous reports affects how students intend to produce their own reports. What comes to motivating students to good quality reports, being able to see the previous year's reports and compare own actions to that could be more effective than knowing that their report might help the next year's students.

In principal, MATLAB Live Scripts should provide a method for integrated instructions and preliminary code for the students. This could be easier for a student to follow compared with instructions and preliminary code in different documents. However, Figure 11 does not suggest a significant difference between these two methods. This might be due to also that many students did not have much preliminary experience in MATLAB, so they did not focus too much on the format of the instructions.

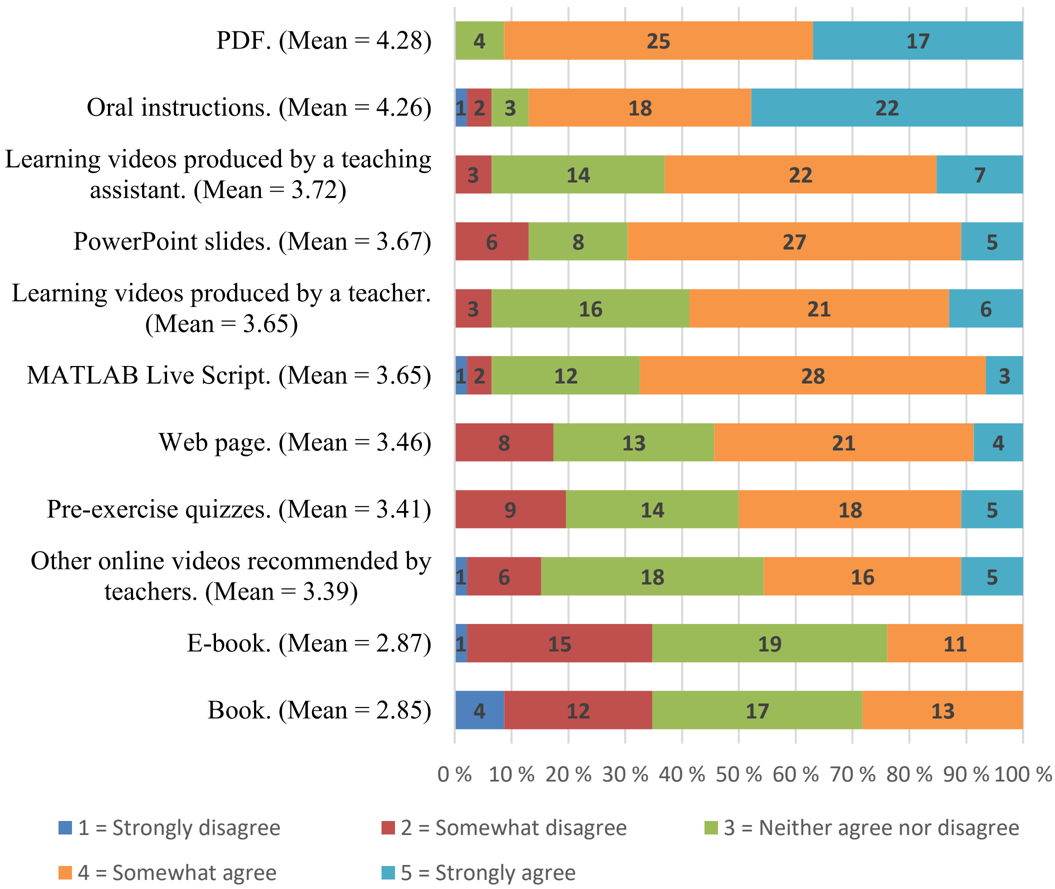


Figure 12. Answer to a claim: "I feel that the following format in exercise instructions promotes my learning."

What is interesting to see is students' good attitude towards instructions as PDF documentation. PDF documentation is given the highest average rank of instruction methods (Figure 12) and it is preferred to Web pages (Figure 12). Contradictory, combined written and video material got more supporters than only written material (Figure 13). Multimedia material can be commonly connected to Web pages and written material to PDF documents. One conclusion might be that students appreciate clear instruction in one document in a familiar format, but complemented with videos if possible. Oral instructions in Figure 12 might relate to laboratory exercises, where a teaching assistant could give instructions to specific needs, thus perceived as useful instructions.

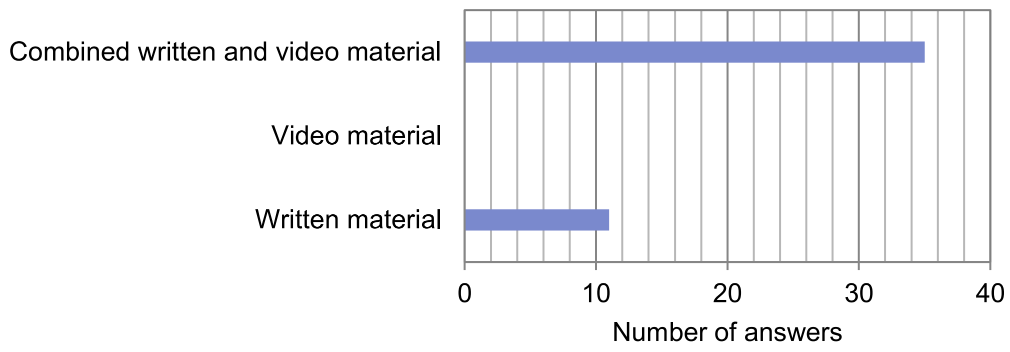


Figure 13. Which of the following is the best way to realize online instructions for an exercise?

3.6 Assessment

The students were asked to count their working hours and assess their own and team members' contributions to the project. It was recommended to do this with the previously mentioned project management spreadsheet. It also included sheets for every team member, where they could write down how many hours they had used for every task and how they would rate themselves and their team-mates in a scale from 0 to 5. Peer-assessment on each member working efforts were asked to give twice during the course.

In addition, students were asked to fill self-reflective questionnaires after each of three laboratory exercises (Appendix 4). The aim of the questionnaires was to find out the perceived development of know-how in 18 items based on course learning objectives. The students answered in a scale from 1 (= not at all/ very little) to 5 (= really much). At the same time, the students should reflect, whether they have reached the learning objectives. The students could also give verbal feedback on the laboratory exercise in the questionnaires.

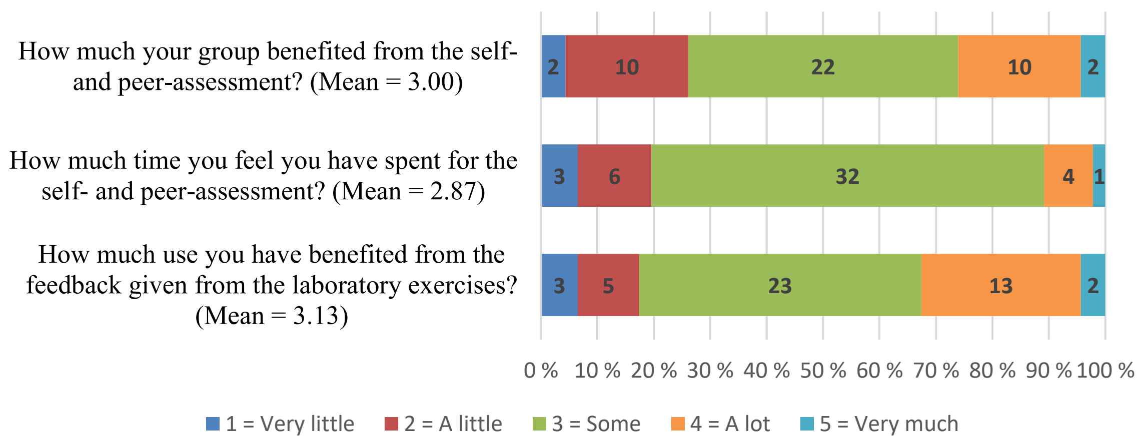


Figure 14. Students' experiences from assessment and feedback.

From Figure 14 and Equation 1, a PEF of 1.05 is calculated for self- and peer-assessment. Students were given feedback for their laboratory exercise assignments if something was lacking from them or if they got wrong results. 33 per cent of the students found that they gained a lot or very much from this feedback (Figure 14). As mentioned, most of the groups did not use the given tool for the peer-assessment, but wrote some kind of short description how each team member had contributed for the 3rd exercise. What is positive, is that none of 20 groups complained that there would have been an unequal share of work, and the reported working hours were nearly equal inside all groups. This suggests that if there is some pressure for student groups to look after their share of work, it will result so that the team members are satisfied with each other's contributions.

3.7 Course process

A process diagram visualizing the phases of the course was made. It included teaching methods color-coded with course learning objectives, allocated to a weekly schedule with assignment deadlines and estimations on weekly working load, showing also how different teaching methods are related to each other with arrows (Figure 15). The purpose of showing estimated working loads and all the assignment deadlines in the same view was to help students' time management and to support them to avoid procrastination. Another objective for the process diagram was to make visible and understandable how the teaching methods are related to learning objectives and assignments.

It may be discussed whether this kind of visualization of the course process can be seen as a teaching method at all. It is true that the process diagram contained information that should be given to students in any course. Seeing process diagram as a teaching method is related to supporting students' time management, and providing a possibility to see the course as a whole and a students' current state in the course. Drawing this kind of process diagram was also found useful for the teachers, as it forced planning the course so that the teaching methods cover the course learning objectives.

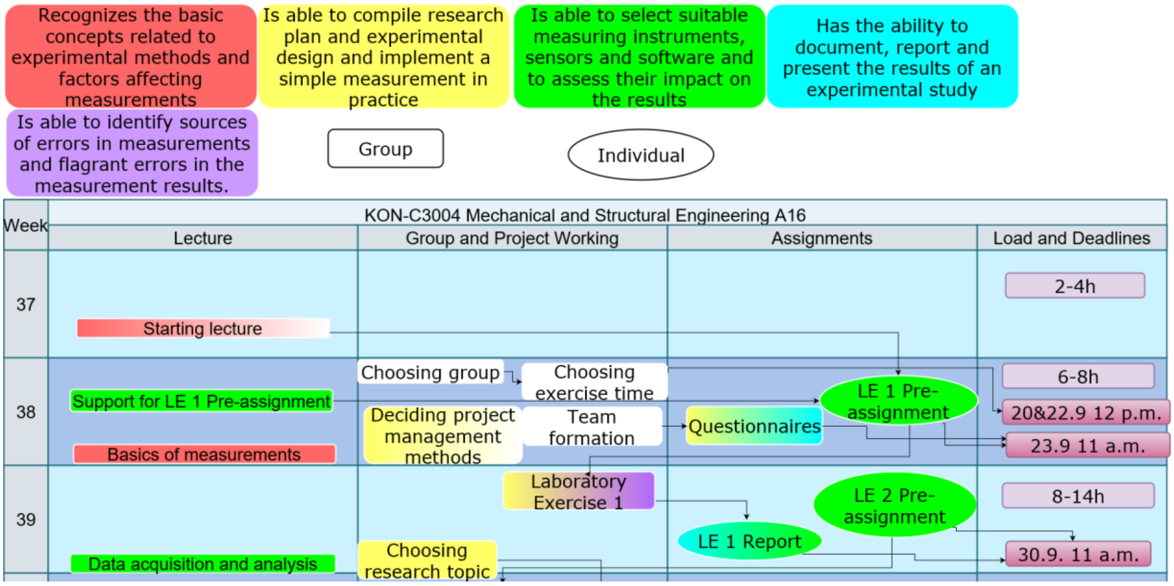


Figure 15. A view from the course process diagram.

In the questionnaire, there was first a question whether the student had investigated the process diagram at all. Five students had not, so 41 students answered the questions related to the process diagram. The students' perceptions on the process diagram are shown in Figure 16 and Figure 18.

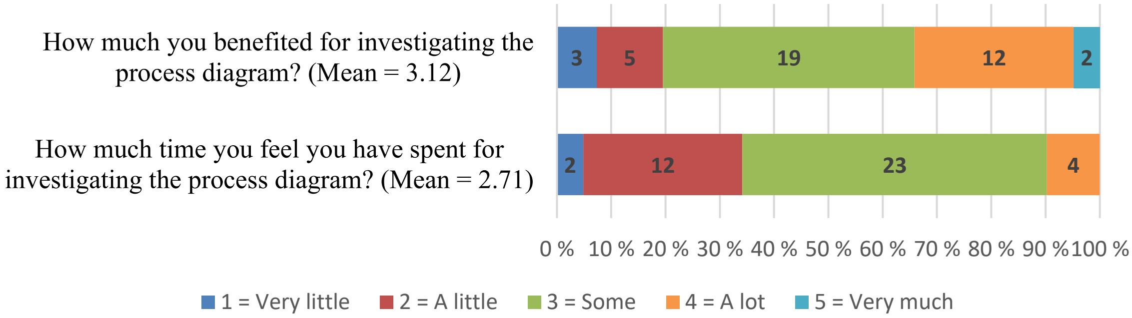


Figure 16. Students' experiences from the process diagram.

Based on Figure 16 and Equation 1, a PEF of 1.15 can be calculated for the process diagram. A high value can be partly explained by that the process diagram also contained basic information that is vital for passing the course.

Figure 17 shows that the students appreciate the most seeing what the assignments are and when they have to be submitted. All the investigated aspects were overall seen more important than not important.

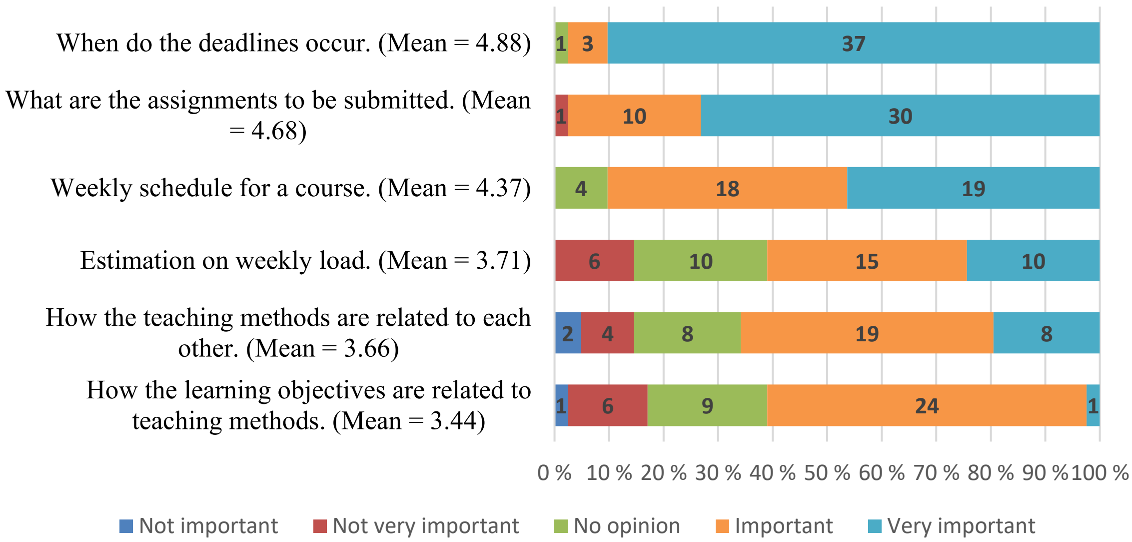


Figure 17. How important do you think it is to show the following items in a view like the process diagram?

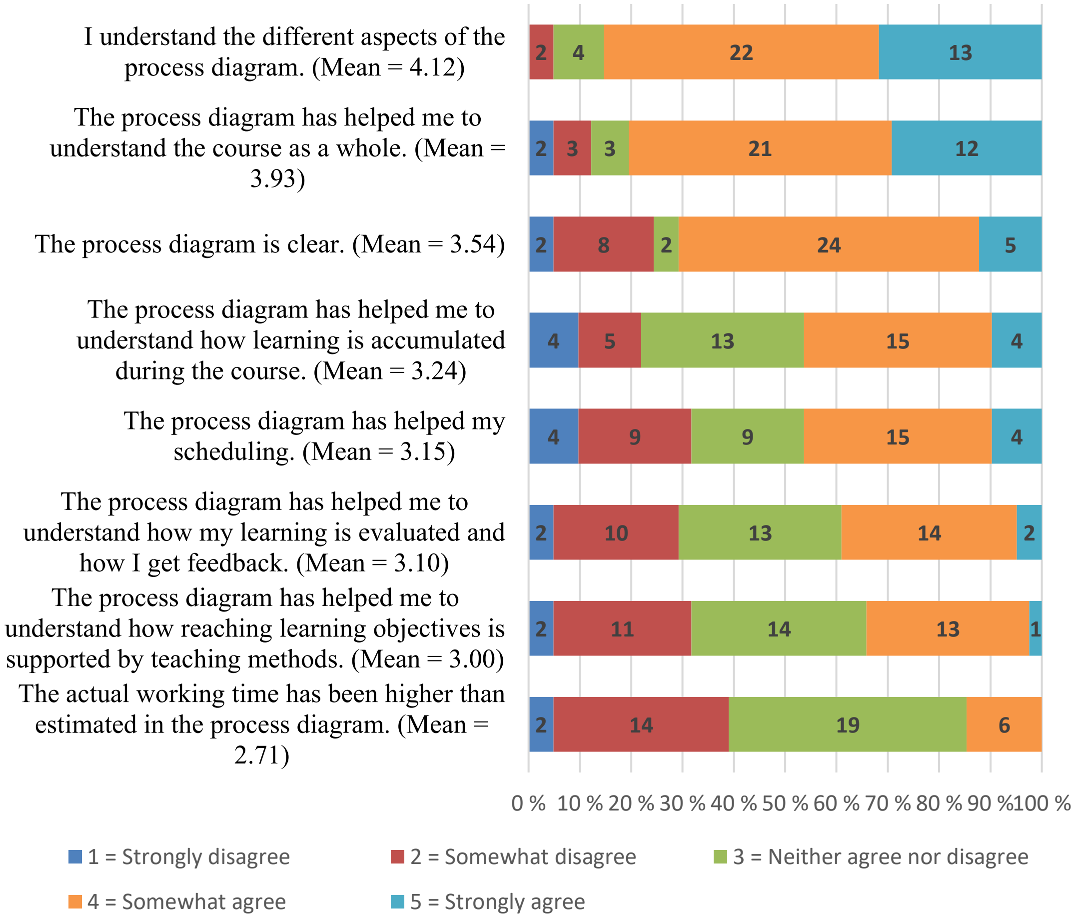


Figure 18. A process diagram as a help for learning.

Some verbal complaints noted that the process diagram was messy. Figure 18 suggests that this was not a problem for all students, as a majority found it clear. As a step of improvement, it has already been thought of that the process diagram could be interactive so that a student could decide what layers would be shown. Some students might only want to concentrate on deadlines. Figure 18 also shows that the process diagram works the best at showing the course as a whole for the students.

3.8 Self-regulation

An extra analysis was done on how did the different methods support self-regulated learning. The question was formulated so that the students reflected how the methods supported them to take responsibility on their own studies (Figure 19). A more comprehensive analysis on the effects on self-regulation would have required to take into account also how the methods affect motivation and meta-cognition. In this case, the analysis wanted to be kept simple.

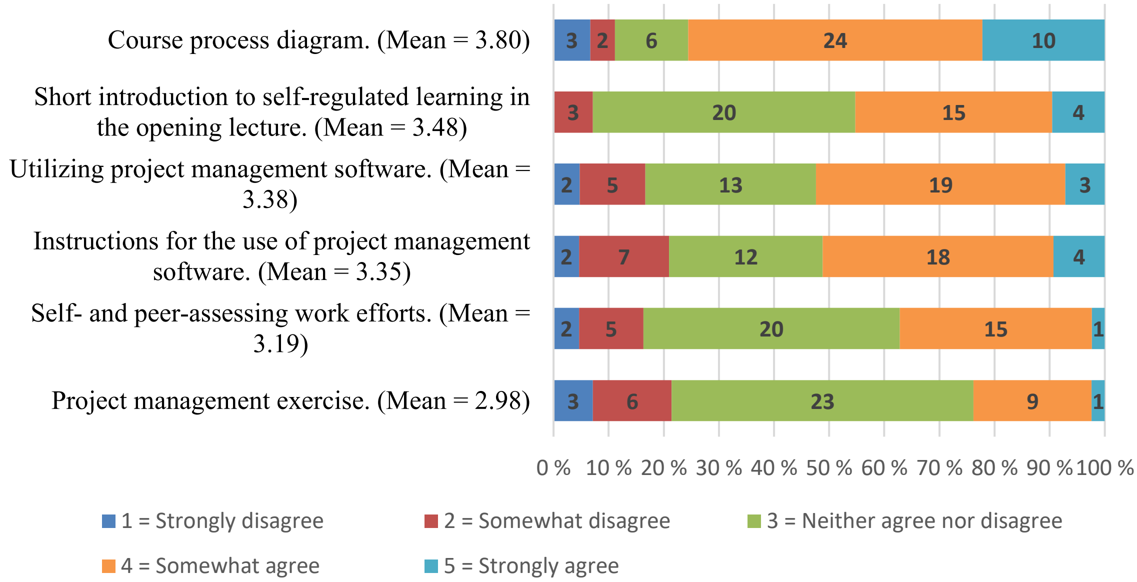


Figure 19. Answer to a claim: "The following method supported me to take responsibility on my own studies."

Figure 19 shows that the course process diagram was overall perceived as the best method of supporting self-regulation as 76 per cent of the answerers somewhat or strongly agreed. About 15 minutes of the opening lecture was dedicated to introduce students to taking the responsibility on their own learning. Many students do not have opinion on this method's effectiveness, but others have found it useful. The instruction and utilization of project management software has also received quite high rates. Although they also got negative grades. This might be related to that some students might have been frustrated with the project management software as they possibly have increased the amount of work without clear benefits in this occasion.

One conclusion is that when students are wanted to be more self-regulated, their needs should be supported in a specific order. First of all, the information of the course should be provided as effectively as possibly. After that, supportive tools for real needs as well as explicit instruction on how to be self-regulated should be provided.

4 Plan for the Biology meets Mechatronics project

4.1 General plan

These plans are based on the discussions with the responsible teachers of Cell and Tissue Engineering (C&T) and Mechatronics Project (MP). In C&T course, there will be 20 students divided into teams of five students attending the Biology meets Mechatronics cooperation. Possibly there will be some other students with a separate course path, but they are not considered here. Learning outcomes for the C&T course are defined as following:

After the course the student has the ability to

1. describe major classes of cells with potential for use for cell-based and tissue – engineering products,
2. present culturing techniques, growth requirements in vitro,
3. discuss the interactions of cells and implantable biomaterials,
4. outline the relevance of Good manufacturing practices (GMP) with case examples of advanced cell based products, biopharmaceuticals and biologics,
5. describe the meaning and implementation of validation, quality control, quality assurance, risk, bioethics and
6. present the product development process of selected products and the key regulatory requirements and the role of regulatory agencies from discovery to bringing products to the market.

From MP course one team with four students will attend the cooperation. The MP students will work as a team of their own, as well as one member in each C&T team. Learning outcomes for the MP course are:

After completion of the course the student is able to

1. design and build a new mechatronic product or test equipment according to" task description,
2. work systematically in a multidisciplinary team,
3. analyze different alternative solutions and to make motivated decisions on basis of this and
4. choose the essential methods, practices and components to design and build a mechatronic machine.

Both courses last for 14 weeks. C&T is a 5 ECTS course with also lecturing content. MP is a 10 ECTS course, mainly based on the students' own actions inside their project. For the sake of this disparity on how much students can spend time on interdisciplinary project, the cooperation is planned so that the MP students are integrated also to the actions of the C&T course.

The topic of the first Biology meets Mechatronics collaboration will be bioreactors and cell culturing. The idea is that at first the students are introduced to a preliminary version of a bioreactor and its building instructions (Appendix 5) that are prepared by a teaching assistant. The functionality of the basic version of the bioreactor contains a possibility to apply a rotational speed from 3 RPM to 30 RPM at about 1 RPM accuracy, and showing this information in an LCD screen.

By the end of the 7th week, the MP students develop a 1.0 version of the bioreactor. The students make small adjustments to the preliminary version of the bioreactor based on discussions with the C&T students. During the first part of the project, each C&T+MP teams are given a task related to the sensors of bioreactors. The 1.0 version is used in the laboratories in weeks 8 to 11. The role of the C&T students is to be experts in cell biology, use the developed bioreactors for cell culturing and give feedback for the MP students. The MP students gather feedback and develop the 2.0 versions of the bioreactors between the 9th and 13th week. An overview of the schedule is shown in Figure 20. Actions for C&T students are shown in yellow, for MP students in blue and for both students in green.

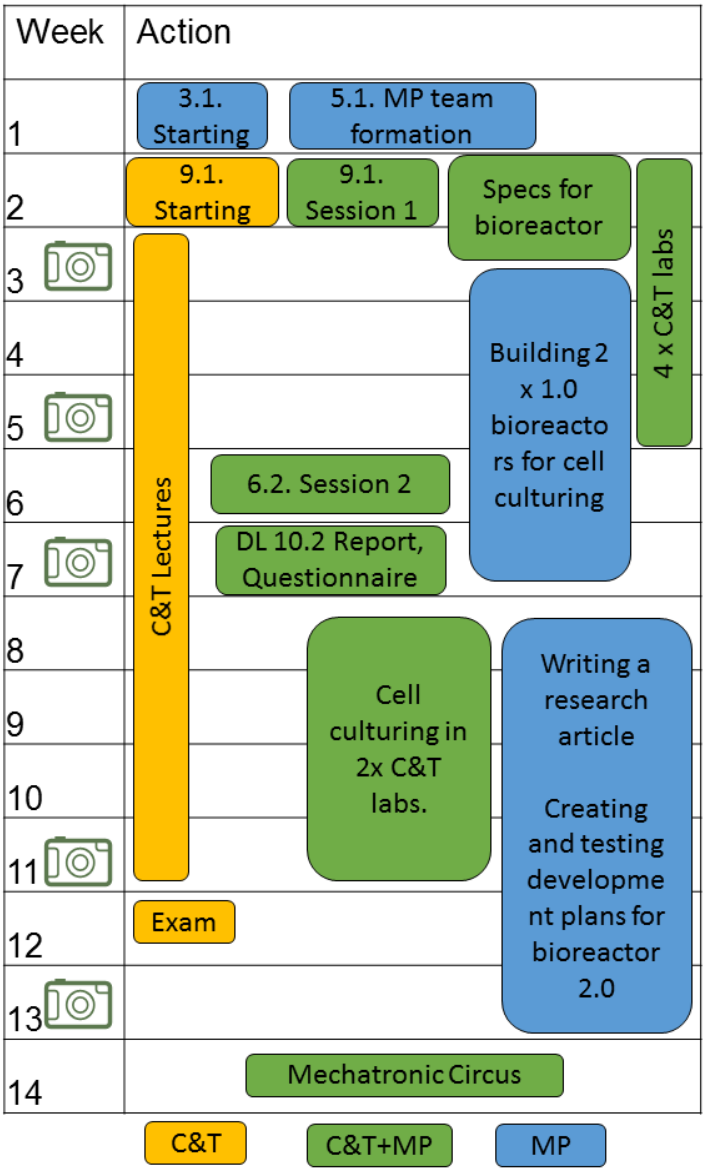


Figure 20. The overview of the courses and collaborative actions.

As seen in Figure 20, the MP course starts a week before the C&T course. This is partly due to the fact that only one team in the MP course will attend the Biology meets Mechatronics actions. This team has to be formed before the beginning of collaboration on the 9th of January in Session 1. Session 1 will include forming the C&T+MP teams with five biology and one mechatronics student each, and getting to know the practicalities.

The 1.0 bioreactors should be ready by Session 2. However, as these bioreactors are only used starting in the 8th week, these bioreactors should be ready latest by the end of the 7th week. C&T+MP teams should also prepare a written report on the sensors of rotating cell culture systems (RCCS) by the Session 2. MP Students can utilize these reports as they make further development plans for the 2.0 bioreactors.

Parallel to all this, the MP team writes a research article. As the first seven weeks are quite intensive, writing the article can be made mostly during the second part of the course. Mechatronic Circus is a closing event for all MP projects. Also the results of the Biology meets Mechatronics projects are presented there.

Assessment in the C&T course is based on an open book exam and the project work, both composing 50 per cent of the grade. The project grade is bases on video reports, filling a reflective questionnaire and the RCCS report. MP students also get half of their grade from the C&T+MP project. The rest of the grade comes from assignments in the MP course, including writing a research article, a wiki page on the project and evidence on the utilization of systematic project management.

4.2 Formation of a team

The formation of a team exercise will be based on the same questions that were tested during the Mechanical and Structural Engineering Laboratory course (Appendix 1). The MP team conducts the exercise and submits a document on their responses. The C&T+MP teams also do the same exercise and submit their response in the 1st video report.

As the MP team is formed by teachers and the C&T+MP teams are formed from students from different majors, it is most likely that there are people in the same teams who do not know each other beforehand. Formation of a team exercise provides clear instructions for the beginning of a team project. The teachers' role is to see the responses to know that the team is working. Watching the responses also helps a teacher to get to know with students and their backgrounds.

4.3 Project management

As previously described, the project part in the C&T course plays a smaller role than in the MP course. For this reason, only MP students are given the instructions for online project management (Appendix 3). The formation of a team exercise should give enough boost for the project management of C&T+MP teams. The written instructions will be supplemented by a video lecture showing some practices on using Google Drive and Freedcamp for project management.

In the Mechanical and Structural Engineering Laboratory course the students were asked in a questionnaire, how there are about to conduct project management. They were also asked to give reports on the contributions of each team member. These tasks motivated students only a limited amount to use external tools for project management. Instead of having questionnaires, the quality of project management should be monitored and assessed to engage MP students in project management. One possibility is to ask MP students to create and update a project plan. Another possibility is to ask reports on the working of the project management. This can also be one chapter in the Wiki-page the MP team will create. Criteria for the quality should be established and the MP team assessed based on that. The criteria could contain for example:

- The planned timetable is clear and reasonable
- The team is able to keep up with the timetable
- Tasks and responsibilities are defined with details and updated during the project
- Every team member works efficiently and gives roughly the same the working effort for the project
- The produced documentation is comprehensive and readable

4.4 Interdisciplinary working

Supporting interdisciplinary working is something that could not be tested during the Mechanical and Structural Engineering Laboratory course, as the students came more or less from the same majors. In the Biology meets Mechatronics projects, the whole idea of integrating students from different courses to common projects strongly enables interdisciplinary working. As complementary methods, creating an interdisciplinary dictionary, reflecting based on a TEDx talk video and praising the team members are used.

An interdisciplinary dictionary is implemented with *Glossary*-activity in *MyCourses*. The idea of the method is that students or teachers can write expressions that they want to have explained from the students of the relevant field. The goal is that all students get a preliminary understanding about the terms of the other field, and about what the people from the other discipline do not understand by default. The students are encouraged to write terms and their definitions actively, however the task is not supposed to be assessed. Teachers can promote the conversation by writing terms they find relevant. An example of a discussion is shown in Figure 21.

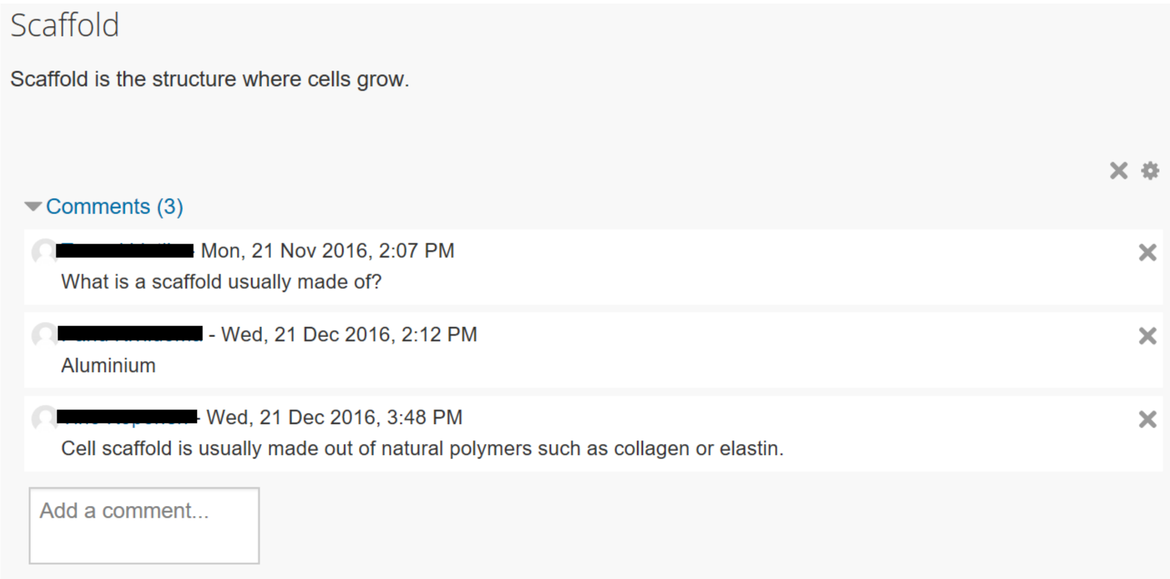


Figure 21. An example discussion in the interdisciplinary dictionary.

As part of their second video report, students are asked to watch a TEDx talk video of an interdisciplinary course on biologically inspired design (Yen 2011). The aim of the task is to promote students understanding on interdisciplinary working by reflection. In the video, Yen discusses projects that interdisciplinary teams have done in her course. The C&T+MP teams should discuss the following questions and add their main ideas to the video report:

- What does it require to build something between disciplines?
- How should interdisciplinary projects be run?
- What is the use of people from different disciplines in a project?
- How can interdisciplinary working methods and communication be supported?
- What is the benefit of engaging oneself in learning interdisciplinary cooperation?
- Was there some ideas or methods in the video you could apply in your project?

As part of the fourth video report, the C&T+MP teams are asked to praise all the team members for something they have done for the project. The aim of this task is to make students to think how people with different backgrounds can contribute to a project.

4.5 Reflective questionnaire

Instead of having several self-reflection questionnaires as in the laboratory course, one bigger questionnaire is suggested. The questionnaire would be open during the 6th week of the courses. The idea is that a teaching assistant makes the results anonymous and gives them to the team. Possibly some values could be compared with the mean values of all answerers. The students should reflect the results as a team and share the main discussion topics inside the 3rd video report. The questionnaire items could include:

- Team working and project working based on Kiviluoma et al. (2016)
- How have I and the other team members contributed to the project. What would I wish more from myself and the others? Actions by Rekonen (2016) can be applied here.
- What have I learned this far and what I still want to learn?
- Time management
    - If the team has been late in some assignment, what has caused the delay?

4.6 Video reports

The cameras in Figure 20 indicate that students should make a mid-term report by the end of that week. The mid-term reports are planned to be submitted in the format of a video. A system called Panopto is used as a system for creating these videos. Instructions on how to make these videos are also done with Panopto by research assistants and presented in session 1, so that students get used to the system. All the video reports should answer the same questions:

- What (interdisciplinary) have we done in the project?
- What have we managed to do well?
- What has caused challenges?
- What are we going to do next?

Moreover, a specific task is given parallel to video reports. The format of these exercises can be videos, documents or quizzes. These are related to the online support of projects and explained more in detail in the following chapters. The other tasks are:

- 1st video: Formation of a team exercise

- 2nd video: Interdisciplinary exercise with a TEDx talk video
- 3rd video: Discussing the results of the reflective questionnaire
- 4th video: Development ideas for the bioreactor. Praise all team members for something they have done.
- 5th video: Final report. This video depicts the whole project. It can include parts from previous videos. Parts of these videos are shown in the Mechatronic Circus.

The videos are evaluated by the teachers or teaching assistants. The students get feedback on their videos.

5 Discussion

5.1 Suggestions based on literature review

Based on the literature review, the following suggestions for utilizing online tools in project courses are made.

Suggestion 1. **A project course should be designed in the pedagogical perspective, combining the benefits of face-to-face and online learning.** In face-to-face occasions, a teacher should for example concentrate on discussion, getting to know the stage of the project and challenging students to metacognitive thinking. E-learning development should not be too tool-oriented, as this might lead the focus in a wrong direction (Willey & Gardner 2009). Rather, tools should be designed to support the chosen pedagogical approach.

Suggestion 2. **Put effort in creating high-quality e-learning material.** Once created material will last forever, though it has to be reviewed periodically to keep it up to date. Material could include written instructions, online videos, lecture slides, self-assessment quizzes or online resources created by others. It is also possible to require students to create material for later teaching purposes, creating a data base of learning material at the same time.

Suggestion 3. **Use an online scaffolding tool to support learning and the progression of projects.** It is possible to use either structuring or problematizing scaffolds. The scaffolds should help reach the essential milestones of a project, including teaming up, agreeing on tools and goals, concept creating, building of a prototype and ending a project. Reflective tasks and feedback from a teacher could be added to the scaffold. In the end, the level of how well a student has internalized the processes provided by the scaffold should be tested to see, whether the scaffold worked as intended.

Suggestion 4. **Provide the documentation of previous similar projects.** A reverse engineering of previous projects approach can be applied. This could include unraveling a physical product and reading the documentation provided by a previous project team. Students could ponder, what parts were used and why, and whether the documentation was good or not and what made it such. Students could also evaluate the quality of the previous project to get an idea what is required from them. Investigating the schedule of a previous project might help to plan their own. Examining the feasibility of the chosen parts, systems and software of a previous project can teach subject-related possible solutions.

Suggestion 5. **Create a dictionary for interdisciplinary collaboration.** Members of an interdisciplinary team could create a dictionary to help understanding the different concepts of disciplines. A possible procedure would work so that a member not familiar with the concept would write it down and try to explain what it means in his or her opinion. Then, a member familiar with the concept would supplement the explanation describing what it means, what it does not mean and what the importance of the concept is. A more sophisticated system could give hints on possible other important concepts that the students had not come up with yet. The quality of the created dictionary could be assessed by a teacher. The explained concepts could be utilized in later teaching events as well.

Suggestion 6. **Teach some software for project management.** A teacher might want to teach some software explicitly to help a student team to get started. Adopting the effective use of software helps students to run their projects and are also valuable working life skills.

On the other hand, spending time to learn to use software with no real value for the project is also frustrating. The extent to how deeply a teacher engages to help students adapting a software tool could vary from telling there are this kind of software to guiding students to the online learning material of the software or to giving lectures and exercises in it.

Suggestion 7. **Acknowledge learning inside project teams.** Teaching should adopt independently working project teams. Teaching efforts should support and monitor this process. As with SPARK, an online tool can be utilized for peer-assessment of contribution to the project and the quality of work (Willey & Gardner 2009).

Suggestion 8. **Use an online pre-questionnaire.** Depending on the needs of a project, different things can be asked in a pre-questionnaire. This might include a student's level of SRL skills, level of substance skills and goals for the project. The measures can be utilized for example in division of teams, where people with the same goals or more-regulated with less-regulated are put to the same teams. Pre-questionnaire could be used also for adjusting teaching to the levels or pre-knowledge and self-regulation of the students. In the end, a post-questionnaire might want to be used to measure development compared with a pre-questionnaire.

5.2 Developed online methods

Compared with what was found in the literature review, the developed online supportive tools were quite light. Developing and adopting online methods for courses takes time. This has affected the results of the questionnaire, as no strong opinions on the methods were found. The main message of the questionnaire could be that online tools should support learning with as clear instructions as possible. Providing other online supportive methods for the needs of the students comes only after this.

The formation of a team exercise (Appendix 1) was seen useful, especially when the students of a team did not know each other beforehand. The exercise aims to support teams in getting started with a project and the division of tasks that were found challenging in the ARTS-ENG-Project questionnaire. In the same way, the project management exercise provided some support for the students to make a decision on how they will manage their project. As in the literature review, the research done suggests that the border of when students should be engaged in the systematic project management process and when not is faltering.

The literature review as well as the questionnaire results welcome the use of previous years' documentation in the orientation of the new students of a course. Based on the research, documentation should be provided in a clear format. The reader of the documentation should be thought of. In line with the principles of blended learning, the students appreciated preliminary exercises before coming into a laboratory. Self- and peer-assessment got a good reception in the questionnaire. The method on how to give this feedback yet needs to be established.

5.3 Developed course plan

Based on the plan in Chapter 4, the effect of the used teaching methods on the interdisciplinary project work should be tracked. When running the projects, also other demands might arise, especially due to the interdisciplinary nature of the projects. Combining students from two different courses from different areas to the same project is definitely worth a research.

The formation of a team and project management exercises are taken to the plan based on the tests. A supplementary video showing some practices in online project management tools should help students to adapt to these practices. In the test course, many teams took an easier road in their project management than suggested. The students were not given feedback on the choices they made. In the future, it could be studied whether discussing these choices with a teacher would provide further support for a team's progress in an effective way.

Supporting interdisciplinary cooperation could not be tested within the limits of this research. Still, two methods are suggested in the plan. As presented in the suggestion 5 based on the literature review, writing a dictionary might help a team to establish a common language. In the plan, an interdisciplinary exercise based on watching a TEDx video is presented to provoke students' thinking on interdisciplinary cooperation. Students' perceptions on these methods should be monitored.

An online questionnaire is planned to be used to make the students the students reflect the working of their team. At the same time, the students revise their knowledge on interdisciplinary working they achieved that far. Sharing the answers inside a group makes a student to learn also other views. A redeeming feature in questionnaires is that teachers get some data out of it. In this questionnaire, teachers' attention could be put on how students feel they have done that far, and what kind of thoughts interdisciplinary working provoke.

Online videos provide an emerging possibility to create and receive documentation. This is why video reports were given a big role in the plan. It should be studied, how students respond to this method of reporting. How much instruction is needed? Compared to written reports, do students prefer to provide video reports and do teachers prefer to watch them? Are there differences in the later use of a video report and a written report?

5.4 Further research

During the research, an idea of combining the accumulated learning and the progression stage of a course to a same tool arose. The developed course process diagram could be the base for showing a student his stage in a process, and self- and peer-assessments for showing the accumulated learning. The tool could include a view for the whole project (Figure 22) as well as a view for each individual (Figure 23). Assessments could be integrated into the tool. Possibly the tool could send warnings to the project team or to the teacher, if the project is not progressing as expected.

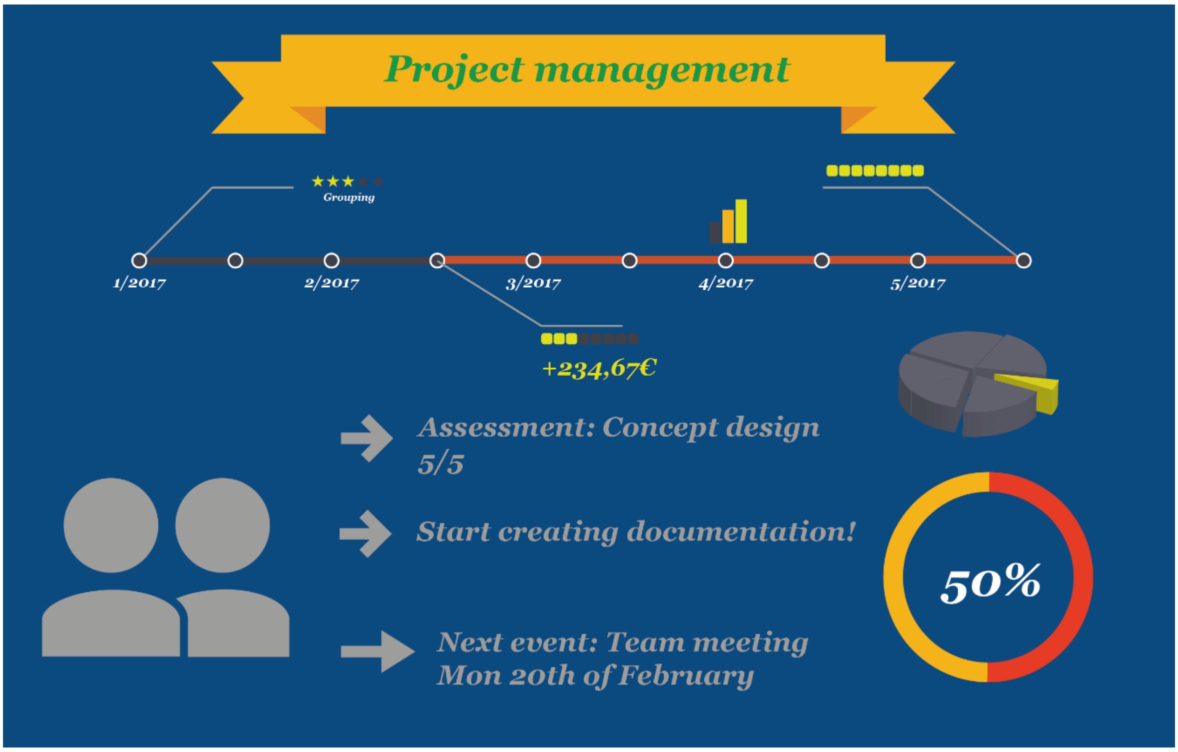


Figure 22. A view for the progression of a project in the planned system.

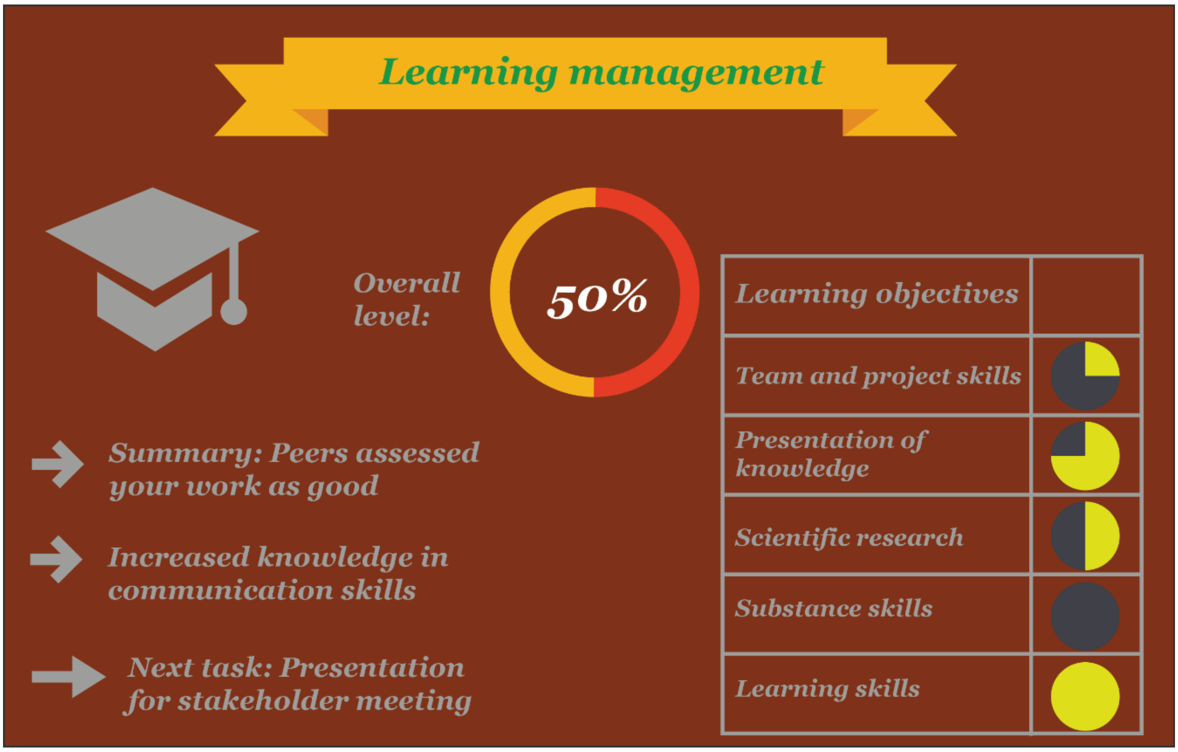


Figure 23. A view for an individual team member in the planned system.

Tapio Auvinen was interviewed as an expert for this idea. He has recently received a doctoral degree in learning technology at the Aalto University. Auvinen found the idea interesting and said that some research in the area has been done, but that no commercial software would be available yet. He went on that in addition to perceived learning, the accumulated learning should be defined by doing exercises created by a teacher. This way, a standard of “if you have done this, you have achieved that learning” can be established. Auvinen found that it would be really valuable for a student to see how the exercises are linked to the course learning objectives. He suggested that this kind of tool could be developed not only for the purposes of the Biology meets Mechatronics pilot but also for other courses. (Auvinen 2016)

Other interesting research topics in the field of the online support of interdisciplinary projects include for example how a team affects one’s learning in a project. What is the difference in putting all the best students to the same team compared with mixing teams with students with varying success in studies? How could automatic tools recognize the problems of a team and propose a solution for their problems? Thinking of not only the learning outcomes of a single project course but also the whole curriculum, it is interesting to ponder how much effort should be put in teaching students to take responsibility on their own learning. Because after all of this buzzing about digitalization, learning comes to the basic situation of students’ ability to learn and teachers’ ability to support this process.

6 Summary

This research provides some understanding on how to utilize internet in interdisciplinary project courses. The literature review takes a deep investigation in learning, teaching and assessment in projects, the peculiarities of interdisciplinary projects, a lighter introduction to project management and execution and possible online tools to be used in projects. This review is put together as practical suggestions in the discussion part.

Challenges of student projects were looked after in a questionnaire preceding the developed methods. The formation of a team and the project management exercises were developed and tested specially to help to start a project and agree on the working methods of a group. The exercises were taken into use in the plan of the interdisciplinary pilot project.

The results of the other tests maybe do not offer practical tools but basic principles on how online tools could be utilized. Online documentation for students should apply multimedia possibilities, yet still be simple and accessible. Students should create such documentation in a project that is usable also afterwards. Self- and peer-assessment is reasonable to carry out with online tools. The benefit of the assessment should be made clear and the assessment tool should be thought carefully. With the course process diagram it could be tested, how students rank the different aspects that a process diagram can provide. Lastly, the effect of different methods on supporting students’ ability to take responsibility on their own learning was studied.

Based on the research, a plan for an interdisciplinary Biology meets Mechatronics pilot projects was created. Online methods for supporting interdisciplinary working and making video reports were presented as new methods.

The research is done for the needs of mechatronics project education in Aalto University. Also other project courses, as well as projects in general can gain from the results. This research hopefully provides a basis for further research on the development of teaching.

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List of appendices

Appendix 1. Formation of a team exercise

The aim of this task is to help to start working in your group. The task includes topics that should be discussed inside your group. Get yourself to some group working facility and reserve time about an hour for doing the task.

1. Getting to know

Get to know what people there are in this team! Here are some questions that may be useful:

- Who you are and where do you come from?
- What are your contact information?
- What are you interests? What are your interests relevant for this project?
- Do you have any previous experience in the topic that could help the project team
- Do you have much other things to do that could affect your contribution in this project?

Write down a couple things relevant to the course that you learnt from each other.

2. Sharing responsibility in your team

Usually it is good to have someone as the coordinator of a team. Small teams can be also more or less "self-managed". But a common problem is that if something is not on someone's response, then it's on nobody's response. The role of the coordinator can be also changed during a project if wanted. The responsibilities of a coordinator could inclu

- Organizing team meetings,

Making sure that the deadlines are kept,

- Response on project management including for example division of tasks,
- Communication with the external parties (teacher).

Other responsibilities inside a team might include

- Producing documentation from the meetings,
- Producing reports and submitting assignments,
- Expert role.
    - Someone can especially concentrate on hard skills.

Are the roles clear in your team? Can you identify any risks in the sharing of responsibility? Write down the decisions you made concerning the sharing of responsibility.

3. Communication

A group might want to have several communication methods. Instant messaging is used for fast share of small information. Example tools include WhatsApp, Facebook Messenger, calling by phone, sending SMS. Slower communication methods are useful for sharing larger information. This can be achieved with e-mails or with cloud services like

Google Drive and OneDrive. There are also tools for having remote meetings, like Adobe Connect (connect.funet.fi) and skype.

What communication tools you are going to use?

Some people want to have confirmation that the message is received. This can improve the understanding of what the other team members have seen. Are you about to use some confirmation habit in communication?

4. Basic working methods

Do you have some other rules in your team? Should there be some punishment for breaking the rules?

Some ideas for possible working methods and rules

- Weekly times when you could meet and work together
- How much beforehand one should inform that
  - She is late from a meeting
  - She can't attend a meeting
- How do you share information if someone couldn't attend a meeting?
- When in a meeting, do you allow time for informal issues as well? Or do you try to work as efficiently as possible without informal chatter?
- How do you make decisions? How do you make sure that everybody's ideas are taken into consideration?

Here are a couple of videos to provoke ideas on forming a group

- https://www.youtube.com/watch?v=ntO5_IAi-8E
- https://www.youtube.com/watch?v=Gizf8KKJ7p0

Write down, what working methods you agreed to use.

5. Goals for the team

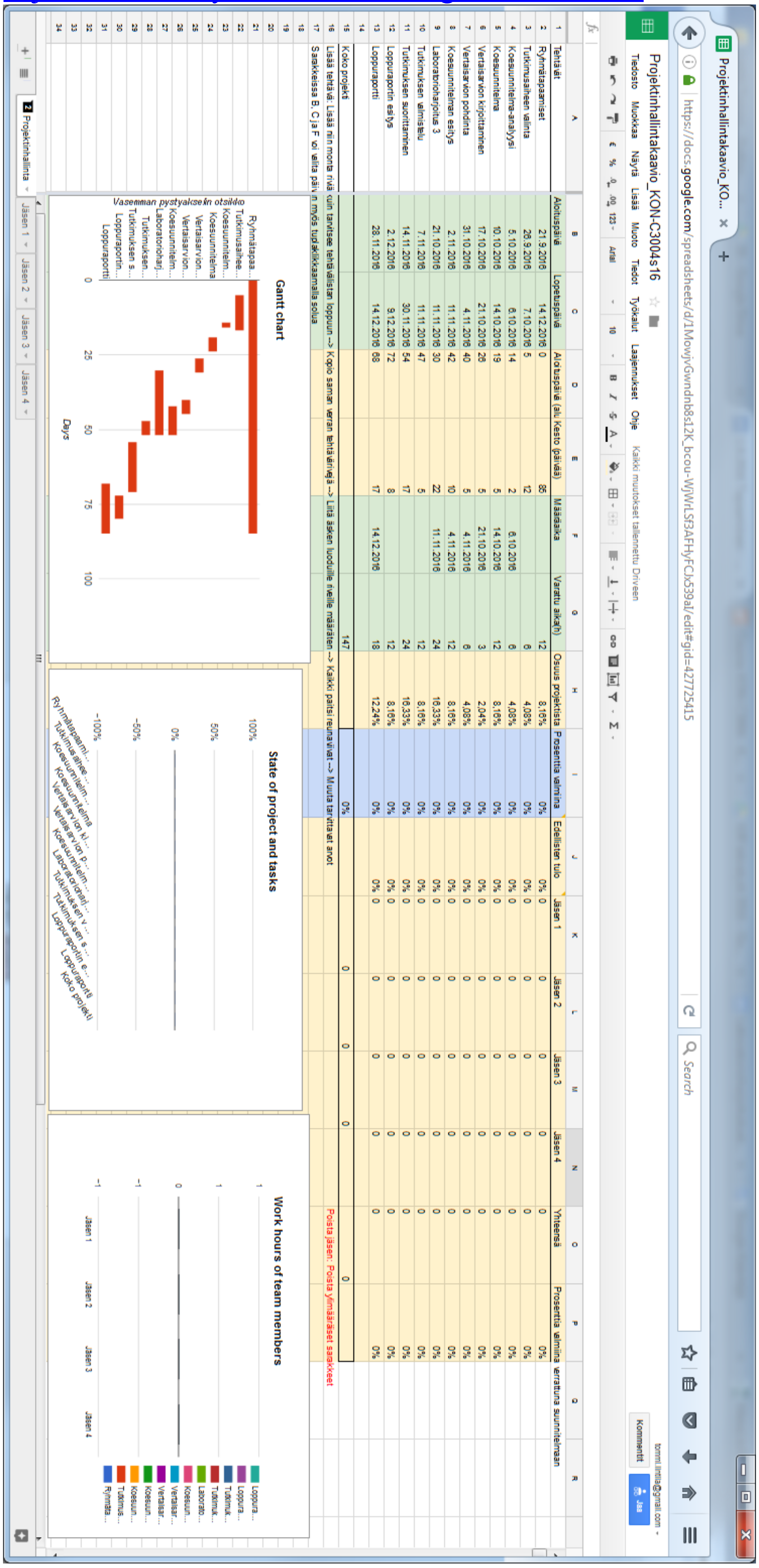
What are the goals of your team? You can answer based on the following aspects:

- Goals for a grade
- Learning goals
- Goals for developing project skills
- Goals for the outcome of the project

Write down the goals of your team.

Appendix 2. Project management spreadsheet

Available also in:
https://docs.google.com/spreadsheets/d/1MowjvGwndnb8s12K_bcou-WjWrLSf3AFHyFCJx539aI/edit#gid=427725415



Appendix 3. Instructions for online project management

There are several challenges in projects, How to plan a schedule? How to share tasks and follow their progression? Is it possible to easily follow the efforts of an individual? Project management software (PMS) are often used to help project management. In the best case the efficiency of a project can be improved with small effort. One should be careful while using a PMS, though. In the worst case the utilization of a PMS causes extra work with no clear benefit.

Two methods for project management based on cloud services are presented here: Google Drive with its features and a free to use PMS called Freedcamp. The aim of these instructions is to provide tools to support project management. What is good project management then? One place to search for answers is the book used in the course TU-C3010 Project planning and management in Aalto University.

Google Drive in project management

Many students are likely to be already familiar with Google Drive. It offers an excellent service for synchronous creating and maintaining of documentation. The basic tools are Google docs for creating documents and Google Spreadsheet for creating spreadsheets.

Google has done their own presentation video for how to use its tools in project management: https://www.youtube.com/watch?v=YHi28IBOdxA.

In this page an example on how to utilize Google Spreadsheet in project management is shown: https://docs.google.com/spreadsheets/d/1wu1hNBU_JMcTJ7hACzgsC1kGLs9vbNIxgzp1db4fiIQ/edit?usp=sharing

You can utilize this spreadsheet as following: Create a copy of the spreadsheet to your know Drive and share it with the rest of your group. The functionalities of the spreadsheet:

- Defining tasks
- Following the progression of the tasks
- Planning and following how much time is used for each task
- Creating a Gantt chart for a schedule
- Following the contributions of an individual team member

This spreadsheet should be adapted to the needs of a project. Columns with automatic formulas are marked with yellow, the planning columns with green and the realization in blue. You decide in your teams what the different tasks are. They can be for example total working hours of a week or meeting, individual working and team working. In the Member-sheets you can mark your hours for each task, and also do self- and peer-assessment.

An option for Google services is Microsoft Office 365 and OneDrive. The y have the same functionalities as Google products. What is good with Microsoft cloud services is that they Word and Excel documents can be modified in a cloud.

Freedcamp – an online project management software

A survey on PMS for student use was made durinng August 2016. As a result, Freedcamp is recommended: https://freedcamp.com/. It is a free, easy to use cloud service.

Features of Freedcamp:

- Task list either as a list or sticky notes
  - Commenting tasks
- Discussion area
- Calendar
- Milestones
  - Tasks can be linked to milestones
- Measuring working time
  - Can be allocated to tasks
- Maximum of 200 MB storing space
- E-mail notifications on the upcoming deadlines

Restrictions of Freedcamp:

- No tool for visualizing the timetable

The user interface of Freedcamp is quite intuitive. You may watch example videos if you wish. They might help you to get faster acquainted with the software.

- https://www.youtube.com/watch?v=DIDCmKPvQhM Duration: 4:33
- https://www.youtube.com/watch?v=YHi28IBOdxA Duration: 14:58

Tips:

- You can add applications in the  -mark in the tool bar (*Get More Applications)*.
- You can manage notifications in *My Account* → *Notification Settings*. You may define there, how many e-mail notifications you wish to have.
- You can export task lists and working time registers to Excel with the Export-tool.

Appendix 4. Self-reflection questionnaire items

Learning objectives for the Mechanical and Structural Engineering Laboratory course.

- 0 = Skills in computer-aided measurements (course staff's own objective to look for)
- 1 = Recognizes the basic concepts related to experimental methods and factors affecting measurements
- 2 = Is able to compile research plan and experimental design and implement a simple measurement in practice
- 3 = Is able to select suitable measuring instruments, sensors and software and to assess their impact on the results
- 4 = Has the ability to document, report and present the results of an experimental study
- 5 = Is able to identify sources of errors in measurements and flagrant errors in the measurement results

In the self-reflection questionnaires, students were asked on how their know-how has developed in the items shown in table 8.

Table 5. Self-reflection questionnaire items and how there are related to learning objectives.

Item	Learning objective
Using MATLAB to handle measurement results	0
Using LabVIEW for measurements	0
Analyzing frequencies with Fourier transform	1
Aliasing	1
Filtering measurement results	1
Using an amplifier in measurements	1
Differential and RSE measurements	1
Circuits in measurements	1
Dynamical measurement systems	1
Calculations related to measurement circuits	1
Conducting measurements	2
Planning measurements	2
Analyzing measurements	3
Ability to evaluate the effect of the measurement system to results	3
Reporting and presentation of results	4
Statistical methods in analyzing measurement results	5
Recognizing errors that appear in measurements	5
Calibration	5

Appendix 5. Instructions for building a bioreactor

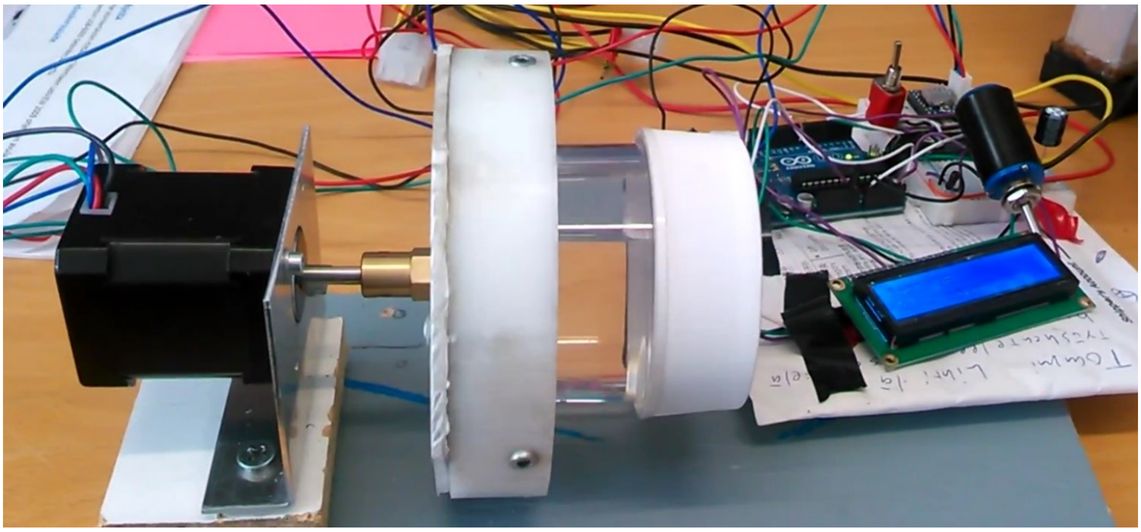


Figure 24. A ready version of the bioreactor.

This document gives instructions on how to build a simple version of a rotary cell culture system (RCCS) bioreactor. The idea of the bioreactor is that by growing cells in a round container with a specific rotary speed the cells are in a continuous free fall, thus enabling 3D cell structures.

The bioreactor is based on Arduino. It reads potentiometer value to adjust the wanted rotational speed. A switch is used to turn the rotation on and off. The rotational speed is shown in a 16x2 LCD screen. A stepper motor with a controller is used to rotate the container. The container can be attached to the system with a 3 mm hex key.

Parts list

Part	Where to get it	Order quantity/ needed quantity	Order Price
Power supply for +5V and +12V	http://www.ebay.com/itm/AC-110V-220v-to-12V-5V-DC-LCD-Dual-Voltage-Power-Supply-Module-Universal-Adaptor-/330943337806?hash=item4d0dc2954e:g:Bp4AAOxy~g5Rw1Rp	1/1	7,41 €
Power supply cable	http://www.ebay.com/itm/3-Prong-4FT-AC-Power-Supply-Cord-Cable-for-Laptop-EU-/182218967523?hash=item2a6d18c9e3:g:9-EAAMXQqWNSJtB-	1/1	1,70 €
Arduino Uno	http://www.ebay.com/itm/Original-Arduino-Uno-R3-ATmega328-Official-Genuine-original-board-Made-in-Italy-/281802283835?hash=item419cb99b3b:g:OeE-AAOSwfZ1WZVGk	1/1	24 €

Nema 17 stepper motor	http://www.ebay.com/itm/Stepper-motor-Nema17-shaft-for-5mm-pulley-RepRap-CNC-Prusa-Rostock-3D-printer-/142032687669?hash=item2111ced235:g:aLAAAOSwc1FXadod	1/1	8,15 €
Toggle switch	http://www.ebay.com/itm/KAYI-SPDT-ON-OFF-ON-Mini-Toggle-Switches-EP07-/281560206113?hash=item418e4bcb21:g:FsoAAOSwYGFUsySl	1/1	0,68 €
100 uF capacitor	http://www.ebay.com/itm/12Pcs-100Uf-50V-105C-Radial-8X12-Mm-Electrolytic-Capacitor-Ic-New-Diy-Develope-C-/301898413929?hash=item464a8c3769:g:tuE-AAOSw14xXEiQ-	12/1	0,86 €
3 pole screw terminal block	http://www.ebay.com/itm/10pcs-3-Poles-3-Pin-2-54mm-0-1-PCB-Universal-Screw-Terminal-Block-Connector-/291553598656?hash=item43e1f2dcc0:g:rhE-AAOSwDNdV5WQY	10/1	0,90 €
Mounting plate for stepper motor	http://www.ebay.com/itm/Alloy-Steel-Mounting-Bracket-holder-For-42mm-NEMA17-Stepper-Motor-42-Steps-hk-us-/201619580069?hash=item2ef176a4a5:g:bfwAAOSwhOVXf9C~	1/1	2,10 €
Breadboard, 400 point	https://www.dx.com/s/breadboard+400+tie+point	1/1	1,82 €
10K precision potentiometer	https://www.dx.com/s/10kohm+precision+potentiometer	1/1	2,95 €
2x16 LCD screen with I2C adapter	http://www.dx.com/s/1602+lcd+screen+i2c	1/1	4,81 €
A4988 stepper motor controller	http://www.dx.com/s/a4988	1/1	2,15 €
Male-to-female jumper	https://www.dx.com/s/20-pack+male+female+jumper	20/8	1,60 €
Male-to-male jumper	https://www.dx.com/s/breadboard+jumper+70-cable	70/20	2,63 €
Brass shaft coupling 5mm	http://www.ebay.com/itm/2pcs-Brass-Shaft-Coupling-Coupler-DC-Motor-Connector-Robot-DIY-Accessories-5mm-/271910036214?hash=item3f4f19e2f6:g:nJYAAOSw-YVXk-wQ	2/1	3,40 €
125 ml container		1	
100x100x3mm plastic sheet		1	
Ø 110/70mm 25mm nylon tube		1	
Some plywood			
M4x20mm hex screw		3	

M4x10mm hex screw		1	
M3x8mm hex screw		4	
M4 washer		1	
M4 spring washer		1	
self-drilling screw, small		3	
self-drilling screw, long		2	
		Total:	**65,16 €**

Building instructions

1. List of tools you need: a soldering iron, screwdrivers, hex keys, a drill and bits, M4 threaded pin, a wire saw.
2. Let’s first create the frame for the container from the nylon tube. Make three 3.3 mm through holes with equal spacing normal to the outer plane of the nylon tube.
3. Drill 7mm holes half way through the same holes done in the previous step.
4. Use the M4 threaded pin to create threads in the holes done in previous steps.
5. Drill three 2.5 mm holes hald way through with equal spacing to the other end of the tube.
6. Take the 100x100mm plastic sheet. Draw the shape of the outer side of the tube to the sheet. Saw this form with a wire saw.
7. Drill 2.5 mm holes to the sheet equally as to the nylon tube.
8. Drill a 4 mm hole into the middle of the sheet.
9. Connect the sheet to the tube with three small self-drilling screws
10. Add the three M4x20mm hex screws to the container frame
11. Create the stand for the motor from plywood. Estimate the amount of plywood needed. Take into account that the dimensions of the nylon tube.
12. Use long self-drilling screws to connect the mounting plate of the stepper motor to the plywood base.
13. Connect the stepper motor to the mounting with M3x8mm hex screws.
14. Connect the brass shaft coupling to the axle of the stepping motor with a hex screw.
15. Connect the container frame to the coupling with a M4x20mm hex screw. Add the M4 washer plate and spring washer plate to the side of the screw head.
16. The structure is ready!
17. When needed, solder jumper wires to the pins of the potentiometer and toggle switch, so that they are possible to connect to the breadboard.
18. Instead of buying a power supply to convert the mains current to 12 V and 5 V, one can utilize an old computer power supply. Instructions for this can be found for example here: http://www.instructables.com/id/ATX--%3E-Lab-Bench-Power-Supply-Conversion/?ALLSTEPS

Wiring

Wiring of the bioreactor is shown in Figure 25. External Ground, +5V and +12V are connected to appropriate terminals in the screw block. Black wires depict Ground, red wires +5V and yellow wires +12V (except in stepper motor wires). There wasn't available a model of the LCD screen with I2C module. To make it clear, the LCD screen Ground is connected to Ground, Vcc to +5V, SDA to Arduino A4 and SCL to Arduino A5. +%V is connected to stepper motor driver in left side row 3. More information on the stepper motor connections can be found in: https://www.pololu.com/product/1182.

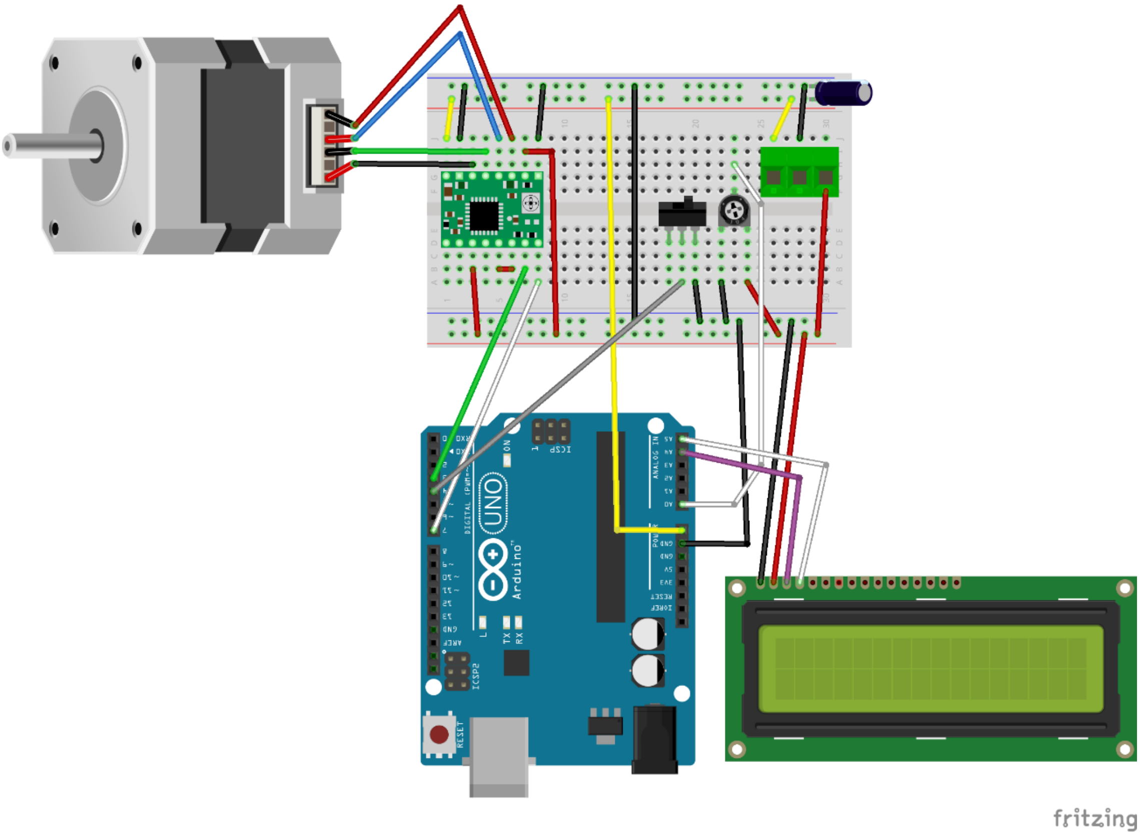


Figure 25. Wiring diagram for the bioreactor.

Software

Here is the code for Arduino IDE:

```
// This software reads potentiometer value and converts it to a speed order to
// a stepping motor. Quarter step mode is applied as default. The applied rotational
// speed in RPM is calculated and shown in an 16x2 LCD screen with I2C adapter

// Define pins and auxiliary variables
int potPin = 0;
int potval = 0;
int potvalold = 0;

int stepPin = 3;
int dirPin = 7;
int stopPin = 4;
```

```
// how many pulses are outputted in sec for motor driver
int pulseFreq = 0;
float RPM = 0;
int stopped = true;
int stopped_old = true;

// Look for help with I2C LCD screen: http://forum.arduino.cc/index.php?topic=128635.0
//define libraries
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

/*-----( Declare objects )-----*/
// set the LCD address to 0x27
// Set the pins on the I2C chip used for LCD connections:
//                    addr, en,rw,rs,d4,d5,d6,d7,bl,blpol
LiquidCrystal_I2C lcd(0x27, 2, 1, 0, 4, 5, 6, 7, 3, POSITIVE);  // Set the LCD I2C address


void setup() {
  // initialize the step pin as an output:
  pinMode(stepPin, OUTPUT);
  // Initialize the pullup resistor for the stop pin
  pinMode(stopPin, INPUT_PULLUP);
  digitalWrite(stepPin, LOW);
  // Define the direction of rotation - this is the only place in code where it is defined
  digitalWrite(dirPin, LOW);
  lcd.begin(16,2);        // initialize the lcd for 16 chars 2 lines and turn on backlight
  delay(1000);
}

void loop() {
  stopped_old = stopped;
  // Read the toggle switch position to see if the user wants to run the motor
  stopped = digitalRead(stopPin);
  if(stopped == HIGH && stopped_old == HIGH){
    // The toggle switch was in stopped position and is still there
    // Let's make sure that no step pulses are given
    noTone(stepPin);
    digitalWrite(stepPin,LOW);
    //Read pot value
    potval = analogRead(potPin);
    // Convert potential reading for a desired pulse frequency
    pulseFreq = map(potval, 0, 1023, 31, 500);
    // Convert pulse frequency to rotational speed
    // RPM = 60*(pulses in second)/(steps in a round)/(stepping mode = quarter = 4)
    RPM = 60*float(pulseFreq)/200/4;
    lcd.setCursor(0,0); //Start at character 0 on line
    lcd.print("Stopped  ");
    lcd.setCursor(0,1);
    lcd.print(RPM);
```

```
    lcd.print(" RPM ");
  }
  else if(stopped == LOW && stopped_old == HIGH){
    // The toggle switch was in stopped position but is now turned on
    // If the desired speed is high enough, apply a ramp up routine
    if(pulseFreq > 250){
      lcd.setCursor(0,0);
      lcd.print("Ramp up  ");
      tone(stepPin, pulseFreq/2);
      delay(1000);
      tone(stepPin, pulseFreq*3/4);
      delay(500);
    }
  }
  else if(stopped == HIGH && stopped_old == LOW){
    // The toggle switch was in running position but is now turned off
    // If the desired speed is high enough, apply a ramp down routine
    if(pulseFreq > 250){
      lcd.setCursor(0,0);
      lcd.print("Ramp down");
      tone(stepPin, pulseFreq*3/4);
      delay(1000);
      tone(stepPin, pulseFreq/2);
      delay(500);
    }
  }
  else{
    // The toggle switch is in running position
    lcd.setCursor(0,0);
    lcd.print("Running  ");
    // tone function can be used for our purposes to send pulses to motor controller
    tone(stepPin, pulseFreq);
  }
  // The void loop is run after every 0,5 s.
  delay(500);
}
```